A CUMULATIVE EFFECTS APPROACH TO WETLAND MITIGATION

A Thesis Submitted to the
College of Graduate Studies and Research
in Partial Fulfillment of the Requirements
for the Degree of Master of Science
in the Department of Geography and Planning,
University of Saskatchewan,
Saskatoon

By:

Jesse Nielsen

PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a Masters of Arts from the University of Saskatchewan, I agree that the Libraries of this University may make it freely available for inspection. I further agree that permission for copying of this thesis in any manner, in whole or in part, for scholarly purposes may be granted by the professor or professors who supervised my thesis work or, in their absence, by the Head of the Department or the Dean of the College in which my thesis work was done. It is understood that any copying or publication or use of this thesis or parts thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to the University of Saskatchewan in any scholarly use which may be made of any materials in my thesis. Requests for permission to copy or to make other use of material in this thesis in whole or part should be addressed to:

Head of the Department of Geography
University of Saskatchewan
Saskatoon, Saskatchewan, S7N 5A5

ABSTRACT

Wetlands are among the most ecologically productive lands in the world, but every year they continue to be lost due to increasing pressures from agriculture, industrial development, urbanization and the lack of effective mitigation to deal with such pressures. Despite environmental assessment processes, policies, and regulations to ensure the mitigation of affected wetlands, wetlands continue to experience a loss in areal extent, but more importantly, a functional net-loss. This is attributed, in large part, to the lack of incorporating cumulative effects principles into project-based wetland impact assessment and mitigation. The majority of activities that affect wetlands are either assessed at the screening level, where cumulative effects are rarely considered, or are deemed insignificant and do not trigger any formal environmental assessment process. As a result, the mitigation of cumulative effects on wetlands is often insufficient or completely lacking in development planning and decision-making. Part of the challenge is that there currently does not exist methodological guidance as to how to identify wetland cumulative effects and corresponding mitigation needs early in the project design process. This research presents a methodological framework and guidance for the integration of cumulative effects in decision-making for project-based, wetland impact mitigation. The framework provides a means for the early indication, assessment, and mitigation of the potential cumulative effects of project developments on the wetland environment, with the objective of ensuring a no-net-loss of wetland functions.

ACKNOWLEDGEMENTS

First and foremost I owe a huge ‘thank you’ to my supervisors Dr. Bram Noble and Dr. Michael Hill. Bram, this thing wouldn’t be half of what it is without your endless suggestions, guidance, editing, and expertise. You truly are one of those few professors who go the extra distance for their students, and in my eyes, that’s the greatest thing a student could ask for. Michael, your calm demeanor always made it very easy and a pleasure to work for you and talk with you. You always reassured me when I needed it most. Together, I could not ask for two better supervisors.

I would also like to thank the other members of my committee, Dr. Xulin Guo, and Dr. Ryan Walker. Xulin, I’m so glad to have had you as a committee member. Your wisdom is always much appreciated and your cheerful personality made it an absolute pleasure to work for you, be your student, and simply, just to get to know you throughout my university years. Lastly, Ryan, I was very pleased when I heard you were going to be my committee chair for the simple reason that I heard you were an easy going, easy to please type of guy, which definitely took any nervousness out of attending committee meetings.

I am very thankful for the financial support provided by Ducks Unlimited Canada through the Industrial NSERC scholarship received for my master’s studies.

I cannot forget to thank my wife, Taren, for helping me get through this journey. For all those nights you waited on me hand and foot while I worked on my thesis, I say, “Thank you”. Without your help and encouragement this thesis would have been a whole lot more difficult.

Finally, but most importantly, I owe this accomplishment to God- for giving me the gifts of knowledge, perseverance, and patience. Without these traits I would have never been able to achieve such a feat. I am humbled to live the life I do, to have accomplished all that I have accomplished, and to be given the opportunities I have been given. I am truly blessed and forever grateful.

Table of Contents

List of Figures

List of Tables

List of Equations

CHAPTER 1

INTRODUCTION

1.0 Introduction

Wetlands are an ecosystem as unique as they are similar. Whether it is a swamp, bog, or peatland, a salt water marsh, or a simple prairie pothole, a wetland is an area where the presence of saturated soil conditions dictates the type of plants and wildlife typically found prolonged in these environments (National Wetlands Working Group, 1997). Wetlands are "super-ecosystems," sustaining more life than any other terrestrial ecosystem on the planet (Costanza *et al*., 1997; Natural Resources Canada, 2004). The importance of wetlands can be summarized by the functions, values, and benefits they provide (Constanza *et al*., 1997; Brown and Lant, 1999; Cox and Grose, 2000). Intrinsic functions such as flood water control, ground water recharge (see van der Kamp and Hayashi, 1998, 2000) and filtration, nitrogen and phosphorus sinks, and controlling water turbidity, are central not only to the sustainability of flora and fauna, but also to the values and benefits that humans derive from these naturally occurring wetland processes – including recreation, flood and erosion control, and food production (Cox and Grose, 2000).

Approximately 148 million hectares of wetlands are scattered across Canada, covering approximately 14% of the country's total land base (Natural Resources Canada, 2004), and accounting for approximately 25% of the world's total wetland area (Environment Canada, 2007). However, despite the seeming abundance of wetlands in Canada, the total number of wetlands, especially in the prairie region, is significantly less than what once existed. Agricultural conversion, the primary cause of wetland loss in prairie Canada, has consumed over 20 million hectares of wetlands since European settlement (Natural Resources Canada, 2004).

The prairie provinces have experienced an estimated 70% decline in wetland habitat due to agricultural development, with approximately 85% of total wetland loss since the early 1800's attributed to agricultural drainage (Natural Resources Canada, 2004, Yang *et al*., 2008).

Today, wetlands are subject to the additional stresses of infrastructure development and other human-induced surface disturbances, including transmission line construction, roadways, pipelines, and railways. While the individual impacts of such stressors may not be cause for concern, the cumulative effects of these activities can result in significant loss of wetland habitat and function over space and time (Dahl and Watmough, 2007). Next to agriculture, for example, road development is amongst the most significant causes of wetland loss and degradation in prairie Canada (Natural Resources Canada, 2004). Road development also presents a particularly challenging scenario for mitigating the impacts of development to wetlands – that is, how to maintain no-net-loss of wetland habitat and function when faced with the task of mitigating the individual effects to many small wetlands (often < 1.0 ha.) over the entire length of a road development project.

Highway twinning is one such example of road development that presents a significant challenge to wetland impact management. Given that most new highway lanes parallel existing lanes, the most desirable form of mitigation, that is avoidance of impacts, is often not a viable option. As a result, regulators and project managers are typically forced to resort to 'impact minimization' and, in many cases, compensation (see Cox and Grose, 2000). As such, cases of successful wetland mitigation in road development projects are rare, and mitigation initiatives often fall short of no-net-loss objectives (NRC, 2001). In the case of the Highway # 1 twinning project, east of Woseley, Saskatchewan to the Manitoba border, for example, a total of 1,864 ha of wetlands were identified within a 2 km corridor along the approximately 132 km highway section to be twinned (Golder, 2003). The compensation plan identified 71.6 ha of wetland habitat that would be lost due to direct project impacts, of which only 20.4 ha were compensated for (Golder, 2006).

Across Canada, wetland loss continues despite the many wetland conservation policies and programs that have emerged over the past several decades (Cox and Grose, 2000; Natural Resources Canada, 2004, Rubec and Hansen, 2009). Perhaps the most significant of these conservation policies and programs, however, is *The Federal Policy on Wetland Conservation* enacted in 1991, and federal and provincial environmental assessment (EA) legislation, which provides a means for wetland policy implementation concerning project developments. *The Federal Policy on Wetland Conservation* aims to conserve wetlands by emphasizing a "no-net-loss of wetland function", based on the mitigation of activities affecting wetlands and, where appropriate, developing compensatory measures (Government of Canada, 1991). One of the most significant challenges to meeting this no-net- loss policy for project developments, however, lies in the traditional approach to wetland impact assessment and the failure of EA to capture both the direct and indirect effects of development on wetlands over space and time (see Bedford and Preston ,1988; Abbruzzese and Leibowitz, 1997; Cox and Grose, 1998; Duinker and Greig, 2006; Noble, 2008).

Compliance with no-net-loss requires mitigation of both the direct and indirect effects of project developments (see, for example, Bedford, 1999; Tiner, 2005), but the majority of activities that affect wetlands are often deemed 'insignificant' and do not trigger any formal EA. In those cases where project effects to wetlands are assessed, attention is typically limited to assessing and mitigating only the direct effects of project activities (see Golder 2003, 2006). As a result, a project's indirect effects, and in particular the effects to many small or seasonal wetlands, are not included in wetland mitigation strategies, leading to a continued net-loss of valuable wetland habitat and functions (Morgan and Roberts, 2003). There are constant and consistent messages in the international literature on the need to consider the cumulative effects of development activities on wetlands (e.g. Preston and Bedford, 1988; Johnston, 1994; Abbruzzese and Leibowitz, 1997; Tiner, 2005); however, there currently does not exist methodological guidance for wetland effects assessment that directly incorporates the consideration of both direct and indirect effects in project impact mitigation design and the EA decision process.

1.1 Purpose and Objectives

The purpose of this research was to develop methodological principles and a framework for the integration of cumulative effects in decision-making for project-based, wetland impact mitigation. More specifically, this research presents and demonstrates a generic methodology for wetland impact assessment that encourages a 'cumulative effects mind-set' to guide the early pre-EA stages of project planning and EA screening processes for linear developments, ultimately leading to mitigation in support of no-net-loss of wetland area and function. This is accomplished by the following research objectives, to:

i. develop a generic wetland cumulative effects assessment and mitigation decision support framework;
ii. demonstrate the framework based on an application to the Highway 11 North twinning project, Saskatchewan; and
iii. identify lessons learned and directions for future application of such frameworks in support of no-net-loss wetland mitigation.

For project proponents, the framework can facilitate consideration of the total effects of project development and wetland mitigation needs in the project planning and design stages, and in the preparation of environmental management plans. For regulators, the framework may provide guidance for screening the need for EA based on the potential for residual effects following mitigation, and to ensure a proponent's commitment to maintaining no-net-loss. The focus of this research is on the process of 'impact assessment' and 'mitigation decision-making', rather than the policy implications of no-net-loss and the assessment results per se, important though they are.

1.2 Thesis Structure

This thesis is presented in five chapters, including the Introduction. Chapter 2 presents a brief review of the current practice of wetland mitigation and discusses some of the key challenges to implementing a cumulative effects approach, followed by the development of a cumulative effects-based mitigation decision support framework. Chapter 3 describes the research methods, including a description of the Highway 11 North twinning project study area, and data collection methods and analytical tools. Chapter 4 presents the results of the application of the mitigation decision support framework to the Highway 11 project, and identifies a 'preferred' mitigation scenario. In Chapter 5, the results of the research are discussed and conclusions drawn regarding the adoption of a cumulative approach to wetlands effects assessment and mitigation decision-making.

CHAPTER 2
ASSESSING CUMULATIVE EFFECTS IN PROJECT-BASED WETLAND MITIGATION

2.0 Introduction

Wetland loss continues to occur in Canada due in large part to the total or cumulative effects of human development activities on the landscape and the lack of appropriate wetland mitigation strategies. Accounting for and mitigating development effects to wetlands in support of a no-net-loss policy objective thus requires the assessment of cumulative environmental effects (Risser, 1988; Bedford and Preston, 1988; Johnston , 1994; Abbruzzese and Leibowitz, 1997; Cox and Grose, 1998; Bedford, 1999; Tiner, 2005). This chapter provides background on the subject of wetlands mitigation, identifies the challenges that must be addressed in order to integrate cumulative effects assessment (CEA) in wetlands mitigation, and presents a generic wetland CEA and mitigation decision support framework.

2.1 Wetland Mitigation and Project-based Cumulative Effects Assessment

Strictly speaking, mitigation means to make less severe, thus serving to balance society's need for economic development with environmental protection (Gutrich and Hitzhusen, 2004). However, mitigation has a number of definitions that stem from diverse sources, each of which use the term differently to suit a particular application or context. From a Canadian federal perspective, for example, *The Federal Policy on Wetland Conservation* emphasizes the mitigation of activities affecting wetland functions and, where appropriate, developing compensatory measures (Government of Canada, 1991). Other definitions focus more on the levels or steps taken to achieve mitigation, such as the Canadian Environmental Assessment Agency's *A Guide to the Canadian Environmental Assessment Act,* which defines mitigation as "the elimination, reduction or control of the adverse effects of the project, and includes restitution for any damage to the environment caused by such effects through replacement, restoration, compensation or any other means" (Government of Canada, 1993). Many other Canadian federal and provincial policies also use the term "mitigation" in the context of wetlands – either defining mitigation as synonymous with compensation, or recognizing compensation as comprising only part of the mitigation process (Cox and Grose, 2000).

In practice, the mitigation of impacts on wetlands is most often limited to compensation measures (Brown and Lant, 1999; Morgan and Roberts, 2003; Gutrich and Hitzhusen, 2004). Compensation is focused on "making up for" the severity of project impacts; a damage control mechanism that, according to Storey and Noble (2002), may prevent a more proactive approach to impact management. The real test of any wetland mitigation is whether it ensures the sustainability of wetlands. Such a task seems simple enough in principle, yet rarely does mitigation fully accomplish such a goal (see Brown and Veneman, 2001; Morgan and Roberts, 2003; King and Price, 2004; Tinker *et al*., 2005).

2.1.1 Adopting a CEA Perspective

The greatest challenge to the mitigation of project effects on wetlands stems from an even deeper issue than that of compensation: effective mitigation can only be determined once the total or cumulative effects of a project are considered, but CEA is rarely incorporated as a routine part of project mitigation planning and impact assessment, or in screening the need to undertake an EA. The result is a continued loss and degradation of many individual wetlands over space and time, which, throughout the course of modern history, has lead to a substantial overall loss of wetland functions (Cox and Grose, 2000). For this reason, there is a growing literature dedicated to understanding the cumulative effects of development activity on wetlands (e.g. Risser, 1988; Bedford and Preston, 1988; Abbruzzese and Leibowitz, 1997; Bedford, 1999; Tiner, 2005).

At the scale of the individual development project, cumulative effects are simply the total effects, both direct and indirect, of that project on a single environmental receptor. In other words, cumulative effects are not about environmental stressors per se, but rather about the total effects on the receiving environment (Therivel and Ross, 2007). Typically, however, wetlands are included in EA and mitigation only if they are likely to be directly affected by the proposed project. Wetlands that are only incrementally or indirectly affected are often not considered, regardless of the potential for significant cumulative loss (see Baxter *et al.*, 2001). Such incremental losses, that collectively have the potential to push an environmental system beyond its sustainable level, often referred to as the "tyranny of small decisions", have plagued project EA since its inception (Noble and Harriman, 2008). Arguably, a cumulative effects perspective that considers the total effects of development on wetland function offers a broader spatial and temporal view of wetland impacts, and represents a more proactive approach to wetland mitigation.

The need for a cumulative effects approach is not new, with some of the first formal writings on CEA in Canada dating back to the early 1980s (e.g. Beanlands and Duinker, 1983; Peterson *et al.*, 1987). That being said, the current state of CEA in Canada is plagued with many problems and is far from being perfected. It has even been described as being "in dire straits" and that continuing down the current path of CEA practice is doing more harm than good (Duinker and Greig, 2006). Despite the general acceptance that project design and EA should intrinsically include the assessment of cumulative effects (Duinker and Greig, 2006; Therival and Ross, 2007), CEA is often an add-on component, referred to by Duinker and Greig (2006) as a "token CEA". This token CEA is evident in the lack of effort frequently taken by project proponents to assess and mitigate the cumulative effects of projects on wetlands during the early stages of project planning. Arguably, this is illustrative of the need for methodological guidance that situates CEA in its proper context in project assessment and mitigation decision making.

2.2 Cumulative Effects Assessment Methodology: State-of-the-Art

The need for explicit, systematic methodologies for assessing and managing cumulative effects is a recurring theme in recent literature (e.g. Baxter *et al*., 2001; Dube, 2003; Duinker and Greig, 2006; Therival and Ross, 2007; Noble, 2008). In a review of Canadian case studies, for example, Baxter *et al*. (2001: 255) argue that, "(e)ffective CEA requires the application of a strategic approach, specifically designed to identify and predict the likelihood and significance of potential cumulative effect problems." In practice however, this is seldom the case; for the same study found that a specific methodology for CEA was lacking in many of the cases reviewed. This alludes to a related problem in the current approach to CEA – CEA is typically performed as an after-thought rather than early in the planning phase of project developments or during the screening stage of EA, where the results are most beneficial to determining the mitigation required to ensure the sustainability of affected Valued Ecosystem Components (VECs). This perspective is echoed by Duinker and Greig (2006: 58), who argue that "for project-level CEA to be meaningful, it must be fully integrated… and not treated as an add-on to the end of the analysis". Cumulative effects considered too late in project planning and EA is of little use to impact management; a common characteristic of CEA that undermines the effort to conduct an assessment of cumulative effects in the first place (Baxter *et al*., 2001).

The practice of implementing a cumulative effects approach to wetland impact assessment and mitigation is challenged by many of the same obstacles to CEA practice in general. Preston and Bedford (1988) were amongst the first researchers to shed light on the challenges to applying CEA to wetlands. A definitive finding of their work is that even though there are obvious benefits to CEA, the process itself will have little effect on decision-making for wetland mitigation if the frameworks and methods for implementation are neither practical nor feasible or are applied too late in the project planning and decision process. The logical solution is to move towards a decision support framework for incorporating cumulative effects that also balances the need for providing proponents and regulators with meaningful results in a timely fashion for development planning and mitigation decision-making. Such a framework would be most valuable for no-net-loss assurance when applied at the earliest stages of project planning, when higher-tiered mitigation options, such as impact avoidance, are still viable options.

2.3 Methodological Requirements for CEA Integration in Wetland Mitigation

What do the above observations offer with respect to methodological requirements for the assessment and mitigation of project cumulative effects on wetlands? First, there is a need to adopt a broader interpretation of wetlands than what is currently the case. The *Canadian Environmental Assessment Act Regulations*, for example, defines 'wetland' as "a swamp, marsh, bog, fen or other land that is covered by water during at least three consecutive months of the year". This definition is limited from a wetland function point of view in that it fails to acknowledge the cyclic wet/dry nature of many wetlands, resulting in the omission of seasonal or temporary wetlands that may not hold water for three consecutive months, but still perform important wetland functions such as flood control, ground water recharge, carbon sequestration, nitrogen sinks and provisions of wildlife habitat (see Semlitsch and Bodie, 1998; Conley and Van der Kamp, 2001; Euliss *et al*., 2006).

Second, there is a need to explicitly recognize the hierarchy of mitigation options for wetlands, commencing with impact avoidance. Cox and Grose (2000) propose a general, wide-ranging definition of wetland mitigation as a process for achieving wetland conservation through the application of a hierarchical progression of alternatives, which include: avoidance of impacts; minimization of unavoidable impacts; and compensation for residual impacts that cannot be minimized. Avoidance and minimization through project design would reduce or even eliminate the time and cost associated with developing more intensive compensatory mitigation options (King and Price, 2004; Noble, 2005). The shortage of science-backed guidelines concerning wetland compensation ratios- the ratio of area mitigated to area lost, across a range of wetland conditions and habitats (see Cox and Grose, 2000; Brown and Veneman, 2001; Morgan and Roberts, 2003; King and Price, 2004), adds an additional layer of uncertainty to mitigation based on compensatory measures.

Third, mitigation decisions must be made in consideration of potential cumulative environmental effects. Much of the effects and subsequent loss from linear developments on wetlands often occur to very small wetlands determined to be individually insignificant, and therefore require no formal impact assessment or mitigation measures. However, it is the cumulative loss of wetlands along the entire length of a development feature, combined with losses from other, nearby or induced human development activities, that is of concern (Cox and Grose, 1998). As Therival and Ross (2007: 371) note, “some cumulative effects are of the type best described as the death by 1000 cuts; each individual effect is insignificant but the accumulation of the many insignificant effects causes a significant adverse effect." Failure to view effects in this manner has led to the continued net-loss of wetland habitat (Abbruzzese and Leibowitz, 1997; Bedford, 1999; Tiner, 2005).

Fourth, cumulative effects and their mitigation must be considered at the earliest stages of project planning and EA decision-making. One of the most pervasive CEA problems is the lack of early identification of potential cumulative effects (Baxter *et al*., 2001). This concern is echoed by Therival and Ross (2007), who argue that amongst the major limitations to CEA are unclear or non-existing methodologies for identifying cumulative effects at the early stages of project planning and impact assessment. Indeed, from an impact management perspective, CEA will be of little use in development planning and impact avoidance if it is performed after impacts have been assessed and project design and mitigation decisions already made.

Finally, and closely related to the above, is that any methodological framework for the integration of cumulative effects in wetland mitigation decision-making must provide for timely consideration of cumulative effects. Abbruzzese and Leibowitz (1997) and Risser (1988), for example, have argued that the main reason for lack of success in wetland CEA and mitigation is attributed to the thinking inherent with cumulative assessment - that assessment must be based on detailed, quantitative scientific analysis involving extensive field-collection and evaluation of information. While this type of analysis does have its place for very large, uncertain, and controversial projects, such analysis presents severe time and financial constraints that would render it impractical within most regulatory settings for more routine and predictable undertakings such as road expansions or transmission line extensions (Abbruzzese and Leibowitz, 1997). According to Therival and Ross (2007: 376), "often only a rough identification of key cumulative effects is needed in order to identify appropriate management measures." The costs associated with obtaining higher accuracy and detailed information about complex cumulative effects pathways in the pre-EA phase quickly becomes unjustifiable, and little benefit is gained for identifying and selecting mitigation options beyond a certain level of information and understanding (Abbruzzese and Leibowitz, 1997).

2.4 Cumulative Effects Decision Support Framework for Wetlands

In the sections that follow, a structured assessment and decision support framework is presented for integrating cumulative effects considerations in wetland mitigation decision-making. The framework is summarized in Figure 2.1, and is based on:

i) a review of international frameworks and guidance for 'good' CEA (e.g. Spaling and Smit, 1993; Smit and Spaling, 1995; Ross, 1998; Hegmann *et al*., 1999; Baxter *et al*., 1999; MacDonald, 2000; Duinker and Greig, 2006; Therivel and Ross, 2007; Noble 2008; Noble and Harriman, 2008; Harriman and Noble, 2008);

ii) current knowledge and practices for impact mitigation (e.g. Race and Fonseca, 1996; Lynch-Stewart *et al*., 1996; Brinson and Rheinhardt, 1996; Cox and Grose, 1998, 2000; Brown and Veneman, 2001; Robb, 2002; King and Price, 2004; Sanchez and Gallardo, 2005; Gutrich and Hitzhusen, 2004; Walters and Shrubsole, 2005; Tinker *et al*., 2005; Hayes and Morrison-Saunders, 2007; Austen and Hanson, 2008; Rubec and Hanson, 2009); and

iii) drawing upon applications of CEA for wetland environments (e.g. Risser, 1988; Bedford and Preston, 1988; Johnston, 1994; Abbruzzese and Leibowitz, 1997; Cox and Grose, 1998; Bedford, 1999; Tiner, 2005).

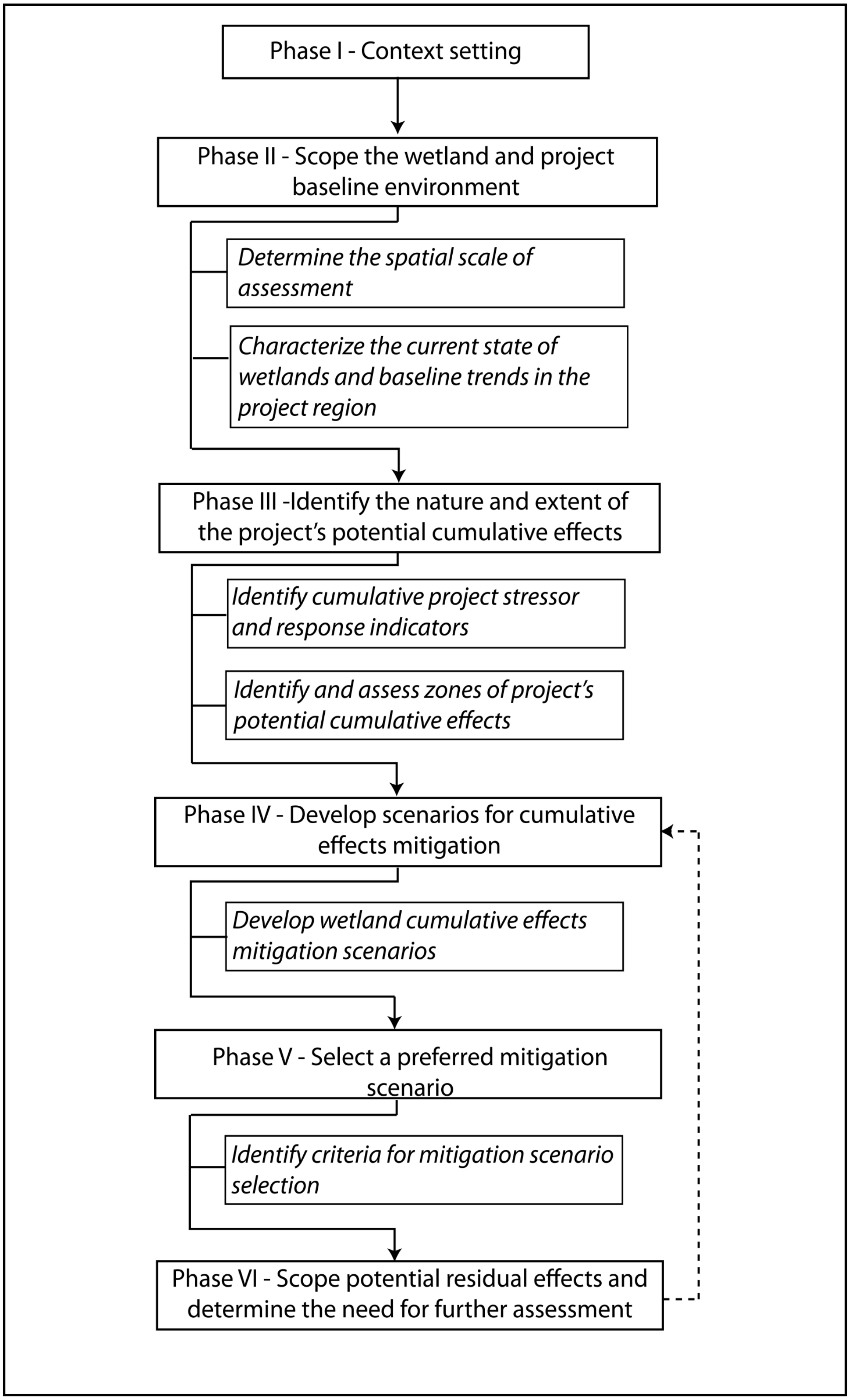


Figure 2.1 Methodological framework for cumulative effects-based wetland mitigation

There is no specific set of techniques that will apply to all wetlands and project development situations, and specific design for each circumstance will increase the effectiveness of any assessment framework (see Noble and Storey, 2001); however, there is a need for a common assessment and decision support methodology that can apply generically to all cases. Although developed based on the current state of practice and needs for wetland CEA and mitigation in Canada, the framework is generic and thus easily transferable to other planning and EA systems and contexts.

2.4.1 Context Setting

Successful project impact mitigation is based on the ability of that project to ensure no-net-loss of wetland functions; thus, understanding wetland functions and the values associated with those functions is a critical step in the assessment process. As Hildén *et al*. (2004) explain, there is a relation between the awareness of context and the success of implementation of an assessment framework. Context refers to the circumstances that have an impact on assessment, and also the conditions that have an impact on mitigation decision-making and implementation. As a first step, there is a need to define and establish the overall purpose and objectives of the assessment, and describe the institutional context within which the assessment will be implemented (Leibowitz *et al*., 1992; Hilding-Rydevik and Bjarnadóttir, 2007). This includes identifying and defining the various policy requirements or permitting conditions that must be adhered to concerning wetlands, identifying stakeholder expectations about wetland mitigation, and, most importantly, describing and understanding the functional values of the wetlands potentially affected in the project area. In particular, and where such information is available, ecological thresholds or levels of acceptable or tolerable change in wetland conditions should be identified and used as targets or benchmarks in the assessment process. At a minimum, understanding context will, in turn, help determine the amount of accuracy and uncertainty that authorities are willing to accept regarding decisions about the development, its potential effects, and prescribed mitigation measures (Abbruzzese and Leibowitz, 1997).

2.4.2 Scope the Wetland and Project Baseline Environment

Environmental disturbances requiring a cumulative approach to effects assessment are those that often involve additive, incremental or synergistic effects over large spatial and temporal scales (Duinker and Greig, 2006). A clear understanding of the cumulative-nature of the problem is thus essential in order to develop an approach to assessment that is encompassing of the key issues at hand, guide description of the baseline environment (Therival and Ross, 2007), and provide for development of mitigation that is better tailored to deal with the added complexity of cumulative impacts. The scoping process serves to focus the assessment and also to delineate the current, cumulative baseline condition of wetlands including past trends, loss over time, and general trajectories of change.

Determine the Spatial Scale of Assessment. Spatial boundaries for the assessment must be established such that they adequately capture the cumulative-nature of development effects on wetlands. A small scale combined with a high level of analytical detail, for example, increases the risk of CEA becoming impractical to implement at the early stages of project planning (Abbruzzese and Leibowitz, 1997; Duinker and Greig, 2006). There are no set guidelines for determining an appropriate spatial boundary for assessing the cumulative effects of linear development features – the choice of boundary will vary depending on the distribution and connectivity of wetlands and local hydrology. Too small, however, and the boundaries will fail to capture the cumulative nature of project effects; too large and CEA can quickly escalate into too many confounding factors and variables, making CEA at the project level unfeasible, impractical, and diminishing its value added to decision making early in the project planning and pre-EA phase.

The size of the assessment area can also be an influencing factor on the significance of the project's cumulative effects identified. In practice, for example, it is often that the larger the spatial area of assessment, the less likely an effect on a particular wetland will be considered significant due the magnitude of the effect in comparison to the overall distribution and extent of wetland habitat (see Therival and Ross, 2007). In other words, an overly ambitious assessment boundary will capture many wetlands that are likely to experience minimal or even insignificant adverse effects from project development. The result is often an interpretation of insignificant cumulative project effects, simply due to the ratio of the total wetlands directly affected by the project to the total wetlands in the assessment area. This is a misinterpretation of the nature of cumulative effects – one whereby an overly ambitious boundary masks the significance of a project's total effect.

Generally speaking, the spatial boundary for a project-based analysis of cumulative effects should capture total wetland disturbances along the entire length of the development, and also extend far enough from the development feature to capture both direct and indirect effects. Research involving the spatial extent of road effects on surrounding environments, conducted by Houlahan *et al*. (2006), Findlay and Bourdages (2000), and Forman and Deblinger (2000), demonstrated that certain effects can extend to a distance >1 km from a roadway. Houlahan *et al*. (2006) reported that adjacent land uses can affect wetland plant diversity 250-300 m away, while

Forman and Deblinger (2000) stated that the road-effect zone averages approximately 600 m in width. Findlay and Bourdages (2000: 93), based on their findings that road densities significantly affect wetland reptile, amphibian, bird, and vascular plant species richness up to distances of at least 2 km from the roadway, state that "(c)urrent Canadian provincial and federal wetland policies are inadequate insofar as the designated buffer zones, where road construction is prohibited, extend at most several hundred meters from the wetland's edge." In the case of the twinning of the Trans. Canada Highway (Hwy. No.1) in Saskatchewan (Golder, 2003), a distance of 1 km on either side of the new lane's centerline was used to delineate the zone for CEA.

Based on findings from this past research, a spatial boundary extending a minimum of 500 m from the center of the linear development feature is needed to capture both direct disturbances to wetlands and also indirect effects such as runoff, sedimentation, and contamination. In any particular application, however, the spatial boundary of assessment should be defined by the distribution of the wetlands themselves, giving consideration to wetland connectivity, distribution, and local to regional hydrology.

Characterize the Current State of Wetlands and Baseline Trends in the Project Region. The overall state of wetlands, not the individual project stressors, should be of greatest priority in the assessment of cumulative effects and mitigation decision-making (see Noble and Harriman, 2008). In other words, the primary focus should be on the sustainability of wetlands – regardless of the individual sources of stress, thus capturing the totality of effects of project stressors. The objective of baseline description is to characterize the current state of the wetland environment in the assessment area, including wetland quantity, size classes, connectivity, and the spatial distribution of wetlands. Given that the current state of wetlands is a function of the effects of current and past stressors (see Hegmann *et al*., 1999), it is important to also understand general temporal trends in wetland conditions. Such information will be valuable in understanding the significance of additional project stress to the wetland environment, and likely future wetland conditions in absence of the project assuming past rates of change and trends prevail.

Due to the often limited availability of baseline data to accurately quantify changes in wetlands and their functions over both space and time for most environments (Semlitsch and Bodie, 1998; Dahl and Watmough, 2007), and due to the complexity of pathways that lead to cumulative change (Harriman and Noble, 2008), a qualitative-based approach is often the most feasible and practical means to provide for an overall understanding of the effects of past activities on the wetland environment. The objective is to determine overall rates or patterns of change in wetland conditions, not to develop a comprehensive set of cause-effects relationships. This kind of exhaustive cause-effect approach has often stymied practitioners of CEA in the past because there are simply too many interconnections, effects, and relationships to describe (Noble and Harriman, 2008).

Consistent with the nature of CEA, attention is on the wetland response or effects, rather than past stressors per se. Often directional impact statements (improving, worsening, etc.) and ordinal scales of measure are commonly used when levels of uncertainty are high and the potential for quantification of data is low; simple +/− projections are often all that is possible and, therefore, the most useful outcome (Therivel and Ross, 2007). Under the best of circumstances, statistical correlations may be discerned between changing stressors and wetland loss; but more direct cause-effect modeling is best reserved for a more detailed environmental impact statement should one be required, or for broader regional-scale cumulative effects-based studies (see Harriman and Noble, 2008).

2.4.3 Identify Nature and Extent of the Project's Potential Cumulative Effects

This is the prospective phase of the framework, asking 'what if' questions about potential cumulative effects on wetlands. The goal is to obtain a vivid picture of the total wetland area that has the potential to be adversely affected by the proposed development. As such, this phase involves identifying indicators of wetland change and methods to quantify the spatial extent of potential cumulative effects.

Identify Cumulative Project Stressor and Response Indicators. Prior to assessing cumulative effects on wetlands, it is important that the project stressors be defined (Leibowitz *et al*., 1992) and some indicator(s) of cumulative change be delineated. The importance of identifying the stressors causing adverse effects is that it provides an indication regarding the potential severity of the functional degradation experienced by particular wetlands, which in turn can contribute to more effective mitigation decision-making through assignment of mitigation efforts tailored to wetlands at greatest risk of degradation. Identifying the stressors or causes of change due to project actions can proceed using well-accepted project-based EA techniques (e.g. GIS, ad hoc approaches, checklists, system models, and expert judgment). The majority of stressors from linear developments are likely to be related to construction activities and, for this reason, can be aggregated as 'surface disturbance' (see Noble, 2008).

The resulting effects to wetland function, which are many and varied and difficult to quantify in absence of intensive field-based science and cause-effect pathway modeling, can be expressed as 'wetland area' - an indicator of, or proxy for, direct, project-induced effects (see Government of Alberta, 2007). Wetland area is the most common and practical indicator of wetland function, primarily because of its relative ease of measure and close relationship to such functions as sediment storage, water filtration, floodwater storage, and habitat provision (Dahl and Watmough, 2007). By assessing the potential loss of wetland area, assumptions can be made regarding the total loss or degradation of a wetland's ability to carry out many of its functions, thereby providing an indirect measure of functional effects (Bedford and Preston, 1988; Abbruzzese and Leibowitz, 1997; Johnston, 1994). In adopting this approach, the assumption can be made that the loss of wetland function will be highest in the areas of highest concentration of stressors or aggregate surface disturbance and, hence, greatest loss of wetland area (Abbruzzese and Leibowitz, 1997).

Identify and Assess Zones of Project Potential Cumulative Effects. Because CEA is concerned with the aggregate effects on wetlands, both direct and indirect effects generated from project activities must be considered (Bedford and Preston, 1988; Abbruzzese and Leibowitz, 1997). Both the quantity and the significance of effects on wetlands are spatially dependent. Delineating 'zones of impact' is thus an efficient means to identify potential cumulative effects, which, in turn, assists in delineating the types of mitigation actions required. This spatial approach to wetland assessment lends itself well to the use of remote sensing and GIS methods and techniques as a practical means of providing and analyzing the information needed to make qualitative assessment decisions (Antunes *et al*., 2001). The nature of these data formats allows for the acquisition, analysis, and presentation of spatially dependent wetland habitat data over large areas, when compared to the time consuming alternative of field-gathered baseline data, which is better suited to a more comprehensive EA application (Ozesmi and Bauer, 2002; Hirano *et al*., 2003; Li and Chen, 2005).

When identifying potential cumulative effects, a distinction can be made between directly versus indirectly affected wetlands, and induced effects. 'Directly affected wetland' is assumed to be the wetland *area* directly altered by the physical activities associated with project surface disturbance (e.g. drainage, dredging, infilling, leveling, grading, packing and paving), for which wetland habitat (and therefore wetland function) is assumed to be completely lost or severely degraded. These wetlands are likely to correlate with, or be in close proximity to, the area of direct surface disturbance. Based on the Government of Alberta (2007) guidelines, any wetland with > 50 percent of its total area directly affected is considered to be a total loss of wetland function.

'Indirectly affected wetlands' are those wetlands not experiencing the direct effects of development activity (i.e. surface disturbance) because of their location. These are wetlands adjacent to the area where development is taking place, but they too may be at risk of functional degradation (e.g. alteration to hydrologic flow patterns, increased sedimentation, alteration of chemical composition, habitat fragmentation) due to indirect and induced effects. Indirect effects, those effects resulting from a change in conditions brought about by the project but not directly related to the physical actions of the project itself, can be assessed by focusing on wetland connectivity in the assessment area. Connectivity is a crucial factor in the functioning of wetlands, especially hydrological connectivity, which is a distinguishing characteristic separating drier upland ecosystems from water-dependent wetland ecosystems (Leibowitz and Vining, 2003). Wetlands with permanent connectivity to those directly affected wetlands are at the highest risk of experiencing additional adverse functional effects from project development, followed by those wetlands with temporary or seasonal connectivity. Isolated wetlands outside the zone of direct effects and with no connectivity to directly or indirectly affected wetlands are at the least risk of additional stress from project development. When using remotely sensed imagery for the identification of connectivity between wetlands, not all connectivity may be visible on a particular acquisition date due to the temporal connectivity that exists between many wetlands. Thus, choosing imagery with acquisition dates corresponding to periods of peak water levels, such as spring on the Canadian prairies (Leibowitz and Vining, 2003), will provide the best opportunity to identify and map spatially and temporally connected wetlands and thus identify potential pathways of cumulative effects (Dahl and Watmough, 2007).

'Induced effects' are those effects that result from additional actions related to, but not directly caused by, the project. For example, a practice that has commonly occurred in prairie Canada when a new linear feature such as a road and an associated road ditch is developed, is that agricultural landowners drain wetlands to the new road ditch as a means to remove water from their land and thus increase total cultivatable area. These induced actions cannot be predicted, but wetlands occurring on agricultural lands that are adjacent to newly formed linear disturbances should be classified as at risk of induced effects and considered in the total potential cumulative effects of project development.

2.4.5 Develop Scenarios for Cumulative Effects Mitigation

Cumulative environmental effects are essentially effects that speak about the future (Duinker and Greig, 2006). Thus, any decision support framework for mitigating cumulative effects on wetlands must be futures-oriented; this demands the explicit creation and analysis of alternative scenarios for mitigating, and evaluating the possible outcomes of each scenario with regard to no-net-loss of wetland function. A scenario is broadly defined as "a hypothetical sequence of events, constructed for the purpose of focusing attention on causal processes and decision points"

(Kahn and Wiener, 1967:6). By comparing multiple mitigation scenarios, proponents and decision-makers are able to obtain a vivid picture of the likely consequences of different mitigation plans, or courses of action (Noble, 2008). In spite of the utility of scenarios, their use is scarce in EA – particularly in project planning and mitigation decision-making (see Duinker and Greig, 2007). Scenarios move beyond making predictions to address questions about the consequences and most appropriate responses under different possible outcomes (Duinker and Greig, 2007). In other words, scenarios do not focus on predictions or forecasts per se, but instead paint a series of pictures about the future using a palette composed of a variety of interchangeable conditions focused on what is possible, what is probable, and what is preferable.

Develop Wetland Cumulative Effects and Mitigation Scenarios. Once potential cumulative effects have been identified, attention should focus on creating and examining different scenarios or plans for cumulative effects mitigation based on spatially-defined zones of direct and indirect effects as a proxy for different scenarios of wetland functional loss. Rather than identify a single mitigation prescription and move forward based on the assumption that it is the preferred or only solution, a scenario-based approach provides the opportunity to examine a range of cumulative effects possibilities and mitigation responses under different assumptions about project stressors and resulting loss of wetland function. Each scenario, and associated mitigation prescription, can then be evaluated against its effectiveness in achieving no-net-loss. The economic costs and complexity of implementation can be openly and systematically evaluated so as to identify a preferred mitigation prescription. In other words, a scenario-based approach allows the project manager to visualize future possibilities and cumulative outcomes under different wetland mitigation scenarios, allowing tradeoffs to be made and a preferred mitigation option to be identified.

Several methods exist for the creation of scenarios (see Duinker and Greig, 2007), with the main approaches being those that adopt a backcasting versus a forecasting perspective. There is no magic number of scenarios that should be considered. Cornish (2004) advises the use of five scenarios, ranging from a pessimistic scenario to an extreme “miracle” scenario. However, each scenario must have distinguishing factors that make it unique in terms of the total spatial extent of affected wetlands due to project direct and indirect effects, and the corresponding mitigation, which, in turn, must be feasible if it is to have any sort of credibility in terms of influencing decisions about the project.

Scenarios can be created through the use of GIS technology by identifying different subsets of the total population of cumulatively effected wetlands to receive mitigation. Scenarios should range from conservative to liberal in terms of the total area and number of potentially affected wetlands considered for mitigation and, in effect, should represent a spectrum of compliance with a no-net-loss policy. For each scenario, a combination of mitigation options should be identified for effects management, based on the mitigation hierarchy from avoidance to various forms of compensation.

Where compensatory mitigation is used, it is recommended that the type of compensation be tailored to the potential severity of functional degradation experienced by the receiving wetlands. For example, compensation options can include restoration of previously existing wetlands, enhancement and protection of existing habitat, and creation of new wetlands. Restoration is considered the most desirable of the compensatory options in terms of maintaining a no-net-loss of wetland functions (Zedler, 1996; Robb, 2002; King and Price, 2004). Options such as enhancement or preservation of already existing habitat have long been considered the least desirable forms of compensation because they do not contribute to any sort of gain in wetland area and therefore contribute to a net-loss of wetland functions (Zedler, 1996; Brown and Lant, 1999).

Wetland protection and enhancement of riparian areas around wetlands can be considered for those wetlands occurring in the zone of indirect effects, where wetlands have limited connectivity or only a small percentage of their total area in the zone of direct effects. Factors to consider when identifying potential mitigation sites include eco-regional differences and that wetland restoration should ideally take place in an area with similar land cover and in the same watershed (Wickham *et al*., 2005; Brooks *et al*., 2006).

2.4.6 Select a Preferred Mitigation Scenario

Scenarios illustrate different possibilities regarding the extent of cumulative effects and associated mitigation options. A decision must now be made as to what portion of potentially affected wetlands, both direct and indirect, will ultimately be included in the mitigation plan. This is a critical stage of project planning, in that mitigation commitments as part of the project design will play a significant role in determining the need for a more comprehensive EA process. In identifying a preferred mitigation scenario, consideration should be given to the implications of the cumulative effects or outcomes identified under each scenario, that is to say, the extent to which no-net-loss will be achieved, and attention should focus on systematically evaluating and comparing the scenarios based on a number of agreed upon criteria (see Noble and Harriman, 2008).

Identify Criteria for Mitigation Scenario Selection. There is no specific set of decision criteria for selecting a preferred mitigation scenario that will apply to all applications of the framework; more or less onerous sets of criteria may be required for any specific application. However, the selection of any option for the mitigation of development impacts on wetlands should consider, at a minimum: i) implications for the sustainability of the affected wetlands (i.e. no-net-loss), and ii) the feasibility of implementing the mitigation actions (see Cox and Grose, 1998).

Consideration should be given to the implications of each scenario in terms of ensuring the sustainability of the affected wetlands when evaluating the effects of the proposed development in combination with other stressors in the wetland environment. The wetlands, not the individual project induced stressors, should be of primary importance. In other words, and in the broader context of wetland policy, the objective is to identify the mitigation scenario, and corresponding set of mitigation options, that best ensures no-net-loss of wetland function in the project area.

With this in mind, the most ambitious mitigation scenario is not necessarily the most realistic scenario, or even the one most likely to be implemented. The feasibility of implementing any chosen mitigation scenario must also be considered. Feasibility is not to be confused with 'ease of implementation'; rather, it refers to such issues as the availability of resources, regulatory controls or requirements, and issues pertaining to land ownership and the acquisition of any lands necessary to implement the mitigation actions. If a mitigation scenario is simply not feasible, it is likely to remain a 'paper promise' without implementation (see Tinker *et al*., 2005). Thus, in choosing a preferred mitigation scenario a balance must be established which simultaneously maximizes fulfillment of a no-net-loss policy and feasibility of implementation.

2.4.7 Scope Potential Residual Effects and Determine the Need for Further Assessment

The final phase of the framework is a feedback loop to project planning, and a feed-forward point to the EA process. For the proponent, if the preferred mitigation scenario is not comprehensive of potential cumulative effects to wetlands, then a decision must be made about the significance of residual effects; those effects remaining after mitigation is performed. This may lead to the need for a reconsideration of the range of mitigation scenarios, changes to the various mitigation options and approaches within the preferred scenario, or the need to demonstrate that any residual effects following mitigation are non-significant.

For the regulator, this is an important phase in determining whether a more detailed, comprehensive EA is required. In principle, the basic test of the need for EA is the likelihood of significant effects on the environment. Thus, it should not be assumed that conformity with proposed mitigation rules out the need for assessment. Mitigation measures should not be ignored when making decisions about the likely significant effects of proposed development, but they should also not form the lead criterion in the decision as to whether an EA is required. In other words, mitigation measures should not be used to circumvent EA or to serve as a surrogate for it. In most cases, mitigation is a series of non-binding actions in a project proposal or environmental management plan (Morrison-Saunders *et al*., 2001). The task of the regulator is to consider the likelihood that such mitigation will occur, identify factors to ensure its implementation, consider the effectiveness of the proposed mitigation measures, and determine a means of monitoring for effectiveness and compliance (Ross *et al*., 2006).

2.5 Conclusion

Incorporating cumulative effects assessment into wetlands mitigation is paramount to obtaining a goal of no-net-loss of wetland area and functions. Several obstacles must be overcome in order to realize such a goal, the least of which include broadening the definition of a wetland, utilizing a hierarchy of mitigation options, consideration of the cumulative nature of project effects, and addressing cumulative effects in the early stages of EA and in a timely manner. Decision making regarding cumulative effects of development projects on wetlands can be aided through the adoption of a cumulative effects decision support framework and the use of scenarios portraying the outcomes of various mitigation options.

CHAPTER 3

RESEARCH METHODS

3.0 Introduction

The utility of a framework for the CEA of wetlands relies on its ease of implementation and ability to produce meaningful results. These two criteria are a function of the methods employed. The methods described in this chapter were chosen such that they can be transferable to other applications of wetlands mitigation assessment, while remaining simple enough for easy adoption by a wide variety of mitigation decision-makers early in the pre-EA and project planning stages. The techniques used here are not new; they are primarily tried-and-true methods in EA practice. The familiarity of the methods amongst a wide spectrum of professionals adds to their likelihood of implementation, which when coupled with an easy-to-understand methodology, makes for a framework with potential for variety of EA applications.

3.1 Louis Riel Trail – Highway 11 North Twinning Project

In April 2007, the Saskatchewan Ministry of Highways and Infrastructure (Department of Highways) received approval to begin construction on the twinning of the Louis Riel Trail-Highway 11, one of Saskatchewan's busiest highways, connecting major centers such as Regina, Saskatoon and Prince Albert. As of 2007, the highway was a 4-lane highway from Regina to north of Saskatoon. The decision to twin the remainder of the highway north to Prince Albert was due to the heavy traffic volume and high number of accidents experienced on that particular section of the highway.

Construction on the highway-twinning project began in late 2007. The Department of Highways was granted an 'Aquatic Habitat Protection Permit', which allowed them to proceed with planned construction activities, subject to the permit conditions, in absence of any formal EA under *The Saskatchewan Environmental Assessment Act*. The only requirement for managing the potential impacts of the road project on wetlands is found under condition 15 of the permit, which states: "Wetland and Upland Mitigation Guidelines for Road Construction (STEC, 2006) shall be adhered to." The decision to grant permission to proceed with the project was based on the conclusion that the project, should proper mitigation be followed, was not likely to cause significant adverse environmental effects and was therefore not considered a 'development' under section 2d of *The Saskatchewan Environmental Assessment Act* (see Government of Saskatchewan, 1980). The project description provided to the regulator, the information on which the decision was made to grant development approval, was a small-scale satellite image of the highway area with a line superimposed showing the proposed twinning route. It was determined later during the construction phase of the project that an EA would be required for the portion of the highway extending through the Nisbet forest.

3.1.1 Study Area

The study area for this research is a 1 km wide corridor, centered on the Highway 11 proposed northbound lane centerline, north of Warman, SK and extending approximately 110 km to the intersection of Highways 11 and Highway 2, approximately 2 km south of Prince Albert, SK (Fig. 3.1). There are no set guidelines for determining an appropriate spatial boundary for assessing the cumulative effects of linear development features; the choice of boundary will vary depending on the distribution and connectivity of wetlands and local hydrology (see Chapter 2).

For this study, a ‘buffer’ distance of 500 m extending from either side of the centerline of the linear development feature was chosen as an appropriate boundary sufficient for the assessment of project-based cumulative effects on wetlands, capturing both direct disturbances from road construction and indirect effects, while limiting the volume of data so as to ensure timely assessment for mitigation decision making.

As of late 2009, approximately 23 km of highway have been twinned and were in use; beginning near Warman and extending north to Hague, SK. Along the remaining portion of the project construction has occurred parallel to the existing highway from Hague to Rosthern, and from the north end of the twinning south to the Nisbet forest, in preparation for the new lane. Wetlands within the 31m right-of-way (ROW) of the new lane have been drained and/or infilled, leveled, graded, and packed to accommodate construction. In many cases, complete wetlands have been lost while others have experienced a significant reduction in surface area due to the infilling of wet areas in the highway’s right-of-way. During field data collection, several instances were observed where wetlands in the right-of-way had been drained into adjacent wetlands just outside the area where highway construction was taking place.

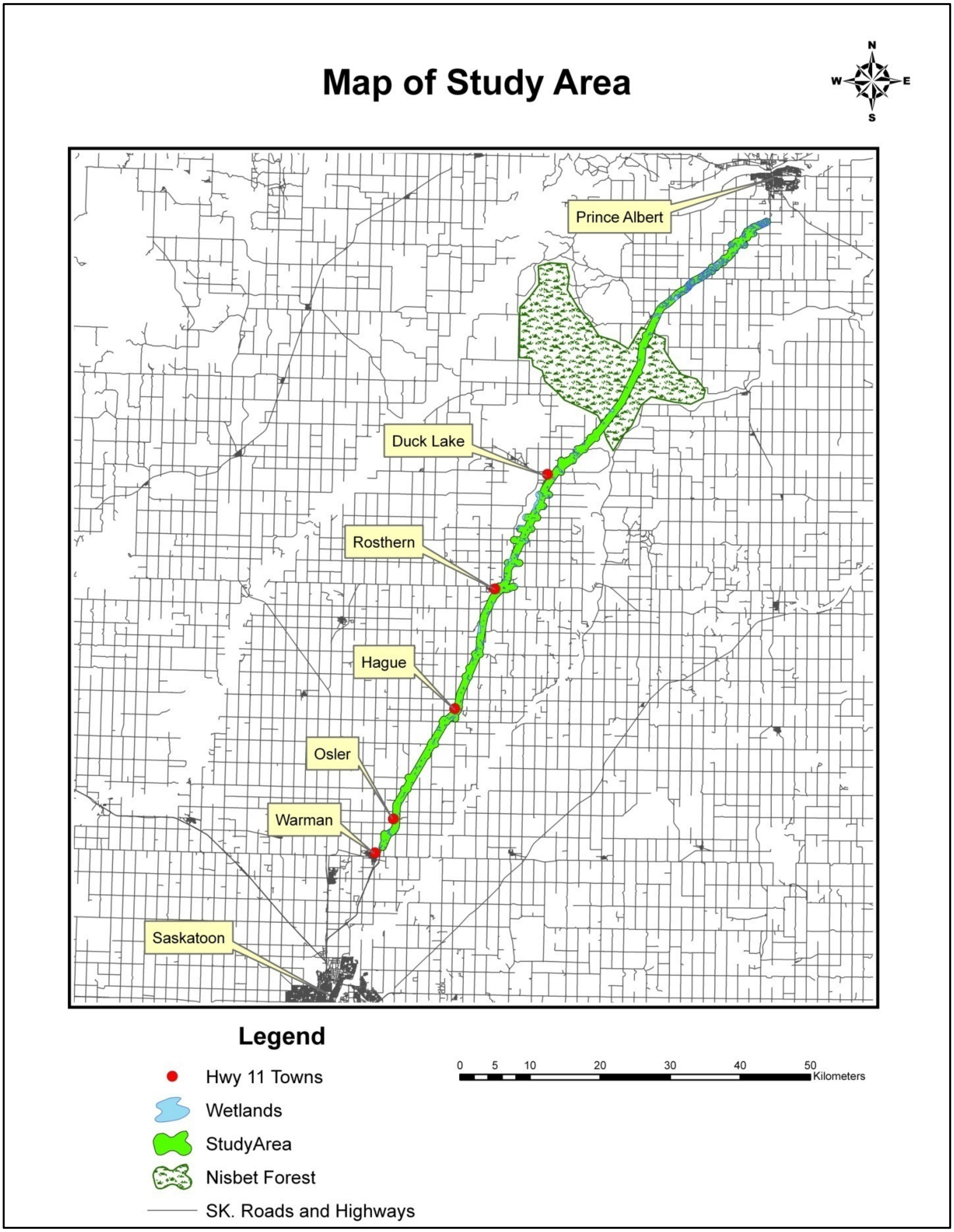


Figure 3.1 Map of study area for highway 11 twinning project

The study area is situated in two ecozones. North of Duck Lake (see Fig. 3.1), the highway is situated in the Boreal Plains ecozone, and in the Prairies ecozone to the south of Duck Lake. The study area in each ecozone can be further classified into ecoregions- Boreal Transitional in the northern half, and Aspen Parkland in the southern half. Wetland habitat in the study area is primarily comprised of prairie marshes, more commonly referred to as potholes or sloughs. This type of wetland occurs scattered throughout the tilled agricultural land, which dominates the majority of the study area. These wetlands may be permanent or ephemeral, depending on fluctuations in water levels throughout the year due to flooding from spring snow melt, evapotranspiration or seepage losses. Water input to these wetlands is from surface runoff, stream inflow, precipitation, and groundwater interaction (National Wetlands Working Group, 1997; van der Kamp and Hayashi, 1998, 2009). Apart from years of extreme drought, the water table typically remains at or below the soil surface, with soil water remaining within the rooting zone for the majority of the growing season (National Wetlands Working Group, 1997).

Wetlands in the study area are comprised of a mixture of vegetation and mudflats. Vegetation includes emergent aquatic macrophytes, chiefly graminoids such as rushes, reeds, grasses and sedges, and shrubs and other herbaceous species such as broad-leaved emergent macrophytes, floating-leaved and submergent species, and non-vascular plants such as brown mosses and macroscopic algae. The spatial variation of marsh vegetation is dependent on gradients of water depths, chemistry or disturbance, and forms as a series of concentric rings or parallel patterns. Marsh environments provide a crucial matrix of habitat for a number of plant and animal species (National Wetlands Working Group, 1997).

The study area is a highly modified, previously altered landscape, with little native habitat remaining. These landscape changes are largely due to agricultural expansion; however, the existing highway lanes, grid road system, and Canadian Pacific Railway have also contributed to surface disturbances. Remnant native habitat persists throughout the area, and a wide variety of flora and fauna species can still be found. Many of these species have adapted to the modified landscape and the disturbances that occur therein.

3.2 Assessment Methods

The overall approach to this study is based on the generic, six-phase assessment methodology and mitigation decision support framework developed in Chapter 2 (see Fig. 2.1). The goal of applying this framework to the Highway 11 case is that it will provide an indication of the project's potential adverse effects on the surrounding wetland environment, and help identify the necessary mitigation measures to ensure a no-net-loss of wetland habitat and function. Two primary sets of methods for data collection and impact assessment were used in this research, namely remote sensing and GIS-based methods, and expert-based multi-criteria analysis of alternative wetland mitigation scenarios.

3.2.1 Assessment of the Wetland and Project Baseline Environment

Highway construction (e.g. draining, infilling, grading, leveling, packing, and paving) is the primary project stressor to wetlands in the study area. 'Wetland area' was used as the sole indicator for evaluating the potential for adverse project effects generated by these surface disturbance activities (see Chapter 2). Because of the inability to efficiently measure and determine the direct relationship between development stressors and actual wetland responses, particularly when dealing with wetland functions, wetland area is one of the most commonly used indicators for wetlands - largely because of its relative ease of quantification (Johnston,

1994) and its ability to serve as a proxy for wetland functions (Bedford and Preston, 1988; Johnston, 1994; Abbruzzese and Leibowitz, 1997; Dahl and Watmough, 2007).

To assess the cumulative or total effects of highway twinning activities on surrounding wetlands, both directly and indirectly affected wetland habitats were inventoried in the study area. Directly affected habitat was considered that total *area* of wetland habitat located within the zone of direct surface disturbance, denoted by the 31 m highway ROW and the 15 m road alignment ROW (collectively referred to as the 'zone of direct effects'), as defined by the Department of Highways, for which wetland habitat and associated functions were assumed to be completely lost. In addition, any wetland with > 50 percent of its total area directly affected by surface disturbance associated with construction activities (i.e. > 50% of the wetland is located in the 'zone of direct effects') was considered to experience a 'total loss' of habitat and function (see Government of Alberta, 2007, Provincial Wetland Restoration/Compensation Guide). Indirect effects, and indirectly affected wetlands, were classified as changes or degradation in the functions of wetlands occurring outside the 'zone of direct effects', up to a distance of 500 m away from the centerline of the new lanes (see Houlahan *et al*., 2006; Findlay and Bourdages, 2000; Forman and Deblinger, 2000). Indirectly affected wetlands were not considered at risk to area loss from construction activities; however, due to wetland connectivity, for example, they were considered at risk of degradation of function due to stress originating within the zone of direct effect. Wetlands adjacent to the zone of direct effect were also considered at risk of induced effects, or effects that result from additional actions related to, but not directly caused by the project (e.g. wetland drainage on agricultural land to newly created roadside ditches).

The adequacy of the ROW as the 'zone of direct effect' was validated by traversing along the maximum visible edge of impacts extending out from the new highway lane's centerline.

Progress was recorded via a Trimble GeoXM© field computer with built-in GPS with 1-3 m accuracy mounted on an all-terrain vehicle. Data were then exported into ArcMap and visually inspected for congruency. Results showed similar spatial positioning between the GIS-generated 31 m ROW boundary and the field-collected actual-effects boundary. Any deviation between the two lines was less than 3 m, which could be attributed to the accuracy of the GPS utilized. Exceptions were when borrow-pits were encountered in the field. These disturbances extended well beyond the boundaries of the 31 m ROW. A total of 20 deviances outside the ROW were recorded along the approximately 40 km traversed, the larger of which were borrow pits, with the maximum disturbance extending approximately 290 m from the centerline of the new highway lanes. In the past, project proponents have flooded borrow pits as a means of compensating for affected wetlands (e.g. Golder, 2006). However, it should be noted that given the extreme depth and steep slope of these pits, they do not provide the functioning of natural wetlands and are not to be considered as adequate compensation for lost wetland area. With a few exceptions, most notably borrow-pits, the established highway ROW matched the maximum extent identified for the zone of direct effect on wetlands, suggesting that the ROW is a good indicator of the distance to which construction activities directly affect wetland area.

3.2.2 Detection of Potentially Affected Wetlands

Assessment of the potential for cumulative effects of highway construction activities on wetlands was conducted using remotely sensed imagery. Extensive research has been conducted on the delineation, classification, and mapping of wetland habitat using remote sensing data, as listed in Li and Chen (2005). The traditional methods for mapping of wetlands are based on aerial photos and multispectral optical satellite imagery (Hirano *et al*., 2003). The procedure used in this research adopted remote sensing and GIS data for the quantification of directly and indirectly affected wetlands. Manual 'heads-up' on-screen digitization of 60 cm resolution aerial photos, and 2.5 m SPOT and 60 cm resolution Quikbird panchromatic satellite imagery was used for this process (Jensen, 2005). Aerial photos acquired on May 23, 2001 were provided by the Department of Highways for approximately 25 km of the northern end of the twinning project. SPOT imagery was available from Ducks Unlimited Canada (DUC) for the entire length of the highway expansion, which consists of a mosaic of six images acquired on June 21, 2005 (two images), April 15, 2005, August 13, 2004 (two images), and July 18, 2004 (Fig. 3.2). Quikbird imagery, acquired on September 1, 2006, was available for a portion of the study area in the shape of an approximate 5 km wide strip, centered on the new northbound highway's centerline, from approximately 4 km south of Hague to 6 km north of Duck Lake (Fig 3.3). All imagery was georeferenced according to the following projected coordinate system: NAD 1983 UTM Zone 13N.

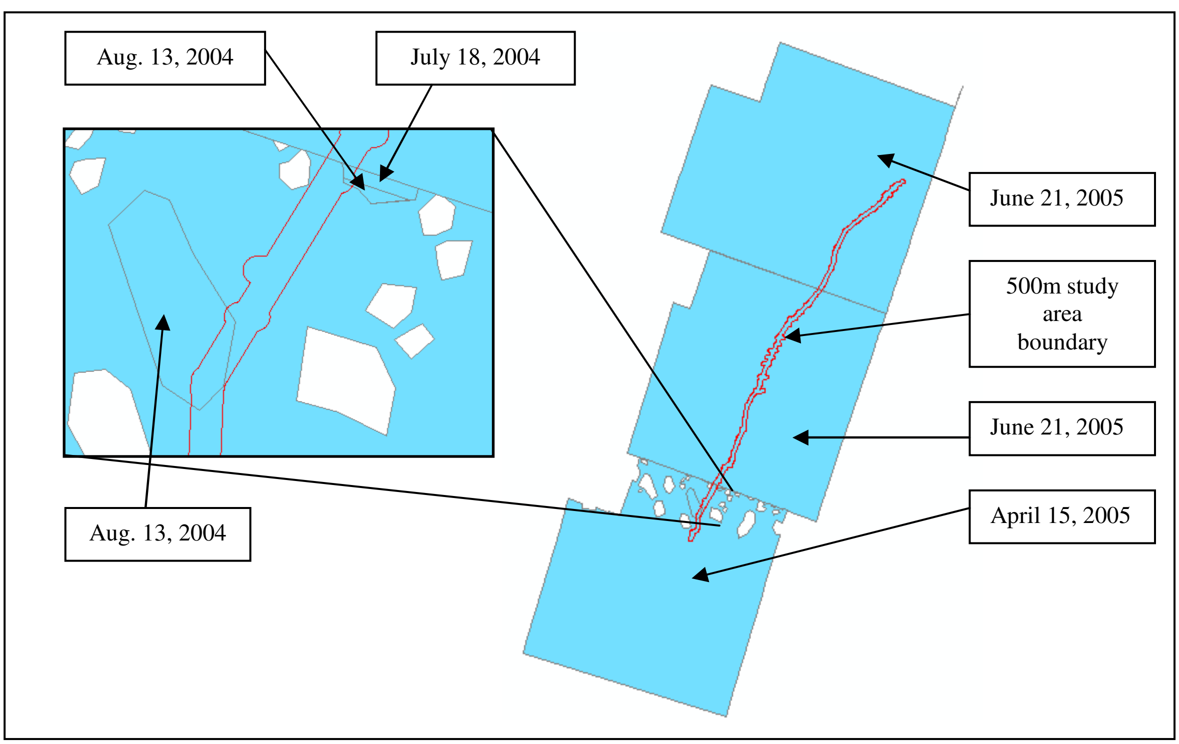


Figure 3.2 Portion of study area covered by each SPOT 5 image acquisition date
***Turquoise polygons represent the ground area shown in each date.**

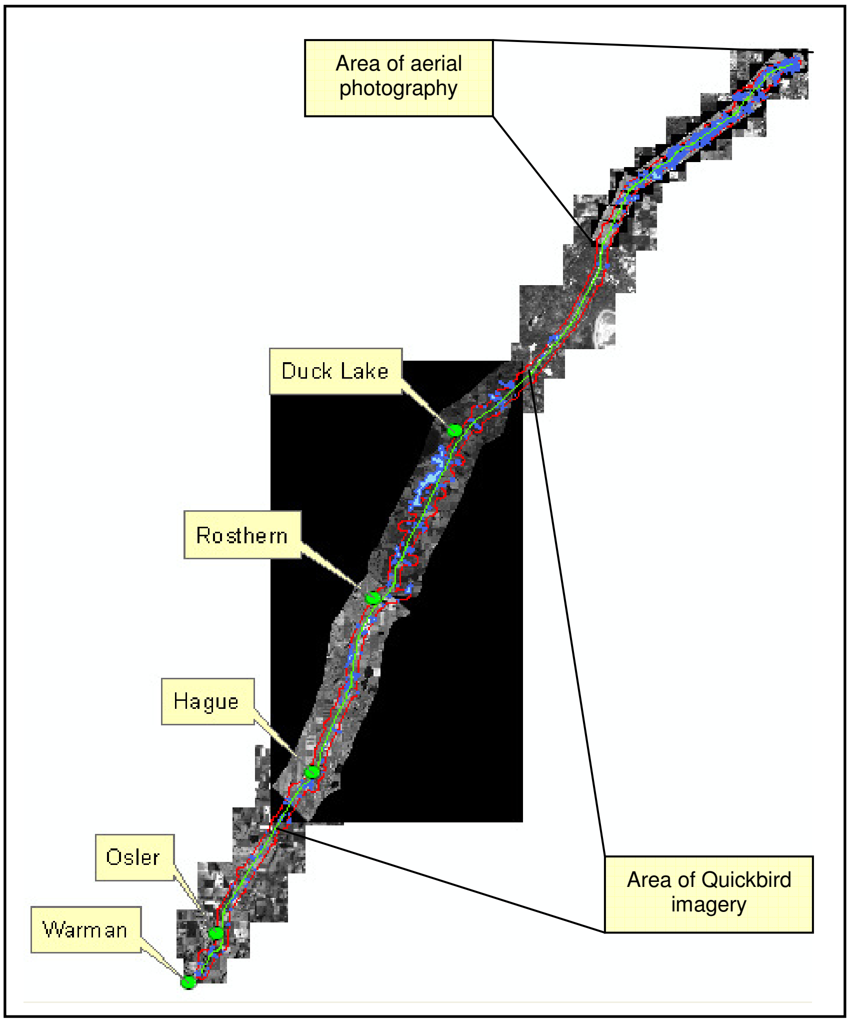


Figure 3.3 Imagery and digitized wetlands of highway 11 study area
*** Blue area- wetlands, red line- study area boundary,**
green line- highway centerline.

A buffer of 500 m, as described above, was applied to the highway and road-correction centerline shapefiles. The two 500 m buffers were then unioned to create a single buffer area, used as the assessment area, and maximum extent for the zone of indirect effects. A union of the 31 m highway and 15 m road-correction buffer produced a single layer shapefile, representing the zone of direct effects for the study area. Digitization of all wetland habitats intersecting the

500 m buffer was done using ArcMap. Following the Saskatchewan Wetland Policy (1995) definition of a wetland, digitized wetland habitat consisted of both the open water and surrounding wetland vegetation of the transitional zone, which is a minimum of 10 m adjacent to the area of open water. Following completion of digitizing, area values (hectares) were calculated for each of the wetlands.

Determination of directly affected wetland *area* was done through the intersection of the zone of direct effects layer with the digitized wetlands layer to create a new directly affected wetlands layer. Using the 'Select by Attributes' function, all wetlands with > 50% of their area intersecting the zone of direct effects buffer were also added to the directly affected wetlands layer. Indirectly affected wetland area was then determined by using the 'Select by Location' function to select and delete all the wetlands from the total digitized wetlands layer that were intersected by the directly affected wetlands layer, thereby creating an indirectly affected wetlands layer.

3.2.2.1 Influence of Precipitation on Total Area of Potentially Affected Wetlands

Environment Canada monthly weather data for 2001-2006 were analyzed to determine the affect of precipitation on wetlands available for mapping during the various image acquisition dates (see Table 3.1). The detection of wetland area using remotely sensed data is dependent on the presence of the saturated environments that distinguish wetlands from other features on the landscape. The more water present on the landscape, the greater the chances of detecting more wetland habitat (Ozesmi, Sand Bauer, 2002). Thus, the amount of wetland habitat available for mapping at a particular date of remotely sensed imagery is a function of the precipitation that the area has experienced prior to the date of acquisition. Because no data were available for any locations in the study area, two locations at each end of the construction area were chosen for analysis: Saskatoon and Prince Albert. Saskatoon and Prince Albert each received significant amounts of precipitation (greater than the 30-year average) during either the month of acquisition or in the month prior. This indicates near-peak levels of water in wetlands during each date of acquisition. This means that for each image, the maximum or near maximum number/size of wetlands was available, making for optimal image capture conditions.

Table 3.1 Monthly precipitation data for study area (mm)*

Saskatoon	2001	2002	2003	2004	2005	2006	Average	30 yr. avg. (1971-'00)
Jan	2.1	2.3	9.0	23.1	18.0	19.5	12.3	15.2
Feb	2.9	6.7	9.9	12.2	23.0	11.5	11.0	10.3
Mar	2.0	8.0	8.7	27.0	29.5	38.0	18.9	14.7
Apr	5.5	14.8	46.2	11.8	16.0	38.0	22.1	23.9
May	21.6	1.5	16.0	27.0	27.5	39.8	22.2	49.4
Jun	38.3	52.2	19.0	79.7	160.5	108.0	76.3	61.1
Jul	52.2	69.5	48.5	75.0	53.5	32.0	55.1	60.1
Aug	6.0	75.2	30.0	73.5	53.5	30.0	44.7	38.8
Sep	7.6	48.9	25.5	21.0	74.0	118.0	49.2	30.7
Oct	6.5	11.1	13.0	28.9	18.0	32.5	18.3	16.7
Nov	6.5	2.4	4.5	trace	29.0	18.0	12.1	13.3
Dec	8.5	6.7	3.5	23.4	20.5	3.5	11.0	15.9
Sum	159.7	299.3	233.8	402.6	523.0	488.8		350
Prince Albert	2001	2002	2003	2004	2005	2006	Average	30 yr. avg. (1971-'00)
Jan	7.8	11.6	7	19.6	14.2	5.6	11.0	16.3
Feb	11	7.6	12.6	16.8	22	10.2	13.4	11.6
Mar	6.6	13.6	9.8	--	20.4	57.4	21.6	16.2
Apr	34.4	16.8	24.6	21	14.4	8	19.9	27.1
May	19.4	16.8	27	--	47.4	62	34.5	47.7
Jun	37.2	29.2	45.8	123.4	87.8	86.8	68.4	72.6
Jul	66.4	24.6	103.6	135.6	40.2	42	68.7	76.8
Aug	5.8	126	40	79.8	108.6	45.4	67.6	58
Sep	10.8	51.2	18.4	50.4	95.2	142.2	61.4	39.5
Oct	6.8	15.4	15.8	37.4	20.4	24.6	20.1	24.1
Nov	7.4	2.2	6.4	4.4	11.8	38	11.7	16.5
Dec	7.8	17	4.2	29.8	21.8	18.2	16.5	17.9
Sum	221.4	332.0	315.2	518.2	504.2	540.4		424.3

*** Highlighted cells indicate the months in which imagery was acquired**
'--' indicates no data available

3.2.2.2 Accuracy Assessment

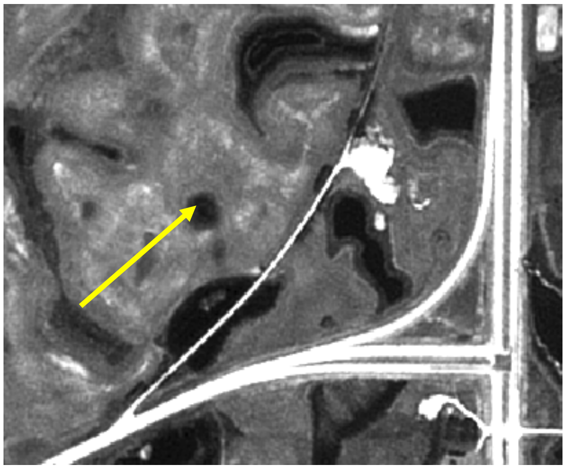
Accuracy of the wetland digitization was verified via ground-truthing. A stratified random sampling scheme was used to select a total of 43 wetlands. Collection dates were June 28-30, 2008, and July 13 and 16, 2008. Four size classes were chosen to represent the distribution of various sized wetlands within a typical prairie landscape (Table 3.2). Perimeters of selected wetlands were traversed while using the ‘create polygon feature’ of the Trimble GeoXM© field computer to create ground-truthed polygons of the wetlands using coordinate readings recorded once every second. Ground-truthed polygons were then exported to shapefiles and overlayed on the digitized layer for display/analysis in ArcMap.

Producer's accuracy represents the probability that the area digitized as wetland on a map actually is wetland on the ground, and is calculated by dividing overlap area for a wetland by the truthed area. User's accuracy represents the probability that a given wetland will appear on the ground just as it is digitized, and is calculated by dividing overlap area for a wetland by the digitized area (Jensen, 2005). Overall accuracy is the average of the two accuracies. In general, accuracy increased as wetland size increased. The lower producer accuracy value for class 1 wetlands was due to the fact that many of these wetlands were actually larger in the field than what was digitized. When digitizing wetlands using the satellite imagery, it is often difficult to distinguish the extent to which the wetland vegetation extends out from the edge of the open water area. As a result, digitization often slightly under-represents the actual area for wetlands, with the greatest affect on small wetlands. Placement of digitized boundary also has a greater effect on accuracies for small wetlands as opposed to larger wetlands (see Fig. 3.4). This is often referred to an ‘error of omission’- not digitizing land as wetland habitat when it should have been.

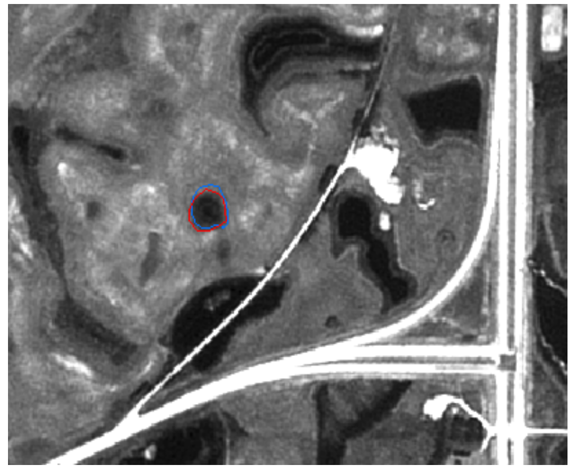
A field-testing exercise performed on July 10, 2008 was conducted to determine the extent to which digitization of panchromatic satellite imagery was able to accurately delineate wetland vegetation. The purpose was to record a GPS waypoint next to very small wetlands thought to be indistinguishable and thus not digitized, on the satellite imagery. The wetlands selected for the exercise had very little to no open water areas, recognizable mainly by the wetland vegetation present. Of the 18 wetlands sampled, all were under 1.0 ha except for one, which represented a class 3 wooded wetland located in the Nisbet Forest. The results of the exercise were that of the 18 wetland areas sampled, only 9 were previously digitized as wetlands. Even the wooded wetland, chosen because of its dense vegetation cover, was not originally digitized because it was not distinguishable from the forested area of the surrounding landscape. Three of the nine undigitized wetlands were not visible/ distinguishable in the imagery. From this exercise, it can be assumed that in addition to heavily forested wetlands, very small wetlands with little open water, recognizable in the field almost solely by the wetland vegetation present, are very difficult to distinguish using even high resolution remotely-sensed imagery, which can lead to their underestimation.

Table 3.2 Accuracy assessment of wetland digitization

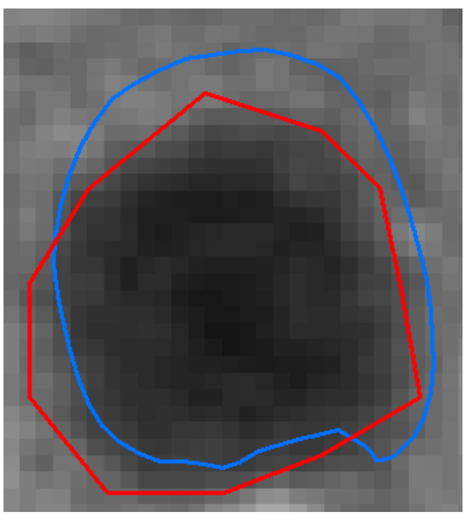
Class Number	Size (ha.)	Total digitized	Number ground-truthed	Producer's Accuracy	User's Accuracy	Overall Accuracy
1	$0 < X < 0.5$	154	15	67	91	79
2	$0.5 \leq X < 2.0$	180	15	86	95	90
3	$2.0 \leq X < 10.0$	106	10	89	89	89
4	$X \geq 10.0$	18	3	91	99	95



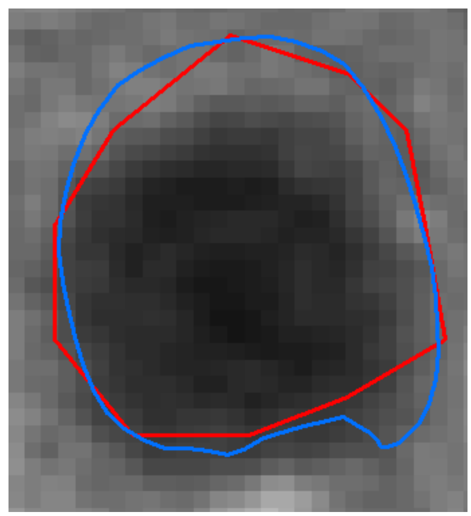
Arrow indicates wetland to be digitized and ground-truthed (scale is 1:8000)



Red circle is the digitized boundary
Blue circle is the actual ground-truthed boundary



Zoomed to a scale of 1:750
Actual delineation of digitized (red) and ground-truthed (blue) boundaries
Producer's Accuracy: 82%
User's Accuracy: 88%



Shifted digitized (red) boundary to better match ground-truthed (blue) boundary
Producer's Accuracy: 89%
User's Accuracy: 96%

Figure 3.4 Example of how delineation of digitized boundary affects accuracy

3.3 Development of Wetland Mitigation Scenarios

Because the majority of wetland mitigation plans are based on the qualitative judgment of wetland experts (Brinson and Rheinhardt, 1996), the benefit of using scenarios is that so-called “expert” decision-makers are not forced to make predictions about uncertain futures based on limited ecological data; rather, they are presented with a series of choices or possibilities concerning potential environmental effects and the most appropriate responses under different sets of circumstances (Duinker and Greig, 2007). In this regard, mitigation planning becomes less of a ‘guessing-game’, and more of an exercise in evaluating possibilities and making explicit trade-offs.

Five scenarios were created for this research, each focusing on the identification of more or less spatially comprehensive groups of wetlands for which mitigation could be undertaken. The scenarios range from conservative to liberal regarding the number and area of wetlands receiving mitigation. Each scenario was created in ArcMap using the ‘Select by Location’ or ‘Select by Attributes’ (in this case *area*) function to identify a sub-set of the total population of potential cumulatively affected wetlands. The scenarios were developed to capture a range of mitigation possibilities, but are certainly not exhaustive, and include the following (Fig 3.5a to e):

- **Scenario 1:** Mitigation is prescribed for all wetland *area* completely within the ‘zone of direct effects’ (Fig. 3.5a). This area is at the highest risk of all wetlands within the assessment area for being negatively affected by project impacts, and is assumed to experience a complete loss of habitat and functions. Any wetlands or wetland area that extends outside the ‘zone of direct effects’ are excluded from mitigation. This scenario is synonymous in most cases with the current status quo for determining mitigation required for wetland loss due to development projects (i.e. mitigation based only on wetland *area* directly affected by a project). Scenario 1 makes no attempt to account for the loss of adjacent, indirectly affected wetland area.

- **Scenario 2:** Mitigation is prescribed for all wetland *area* in the 'zone of direct effects' plus mitigation of those entire wetlands that have >50% of their area within the 'zone of direct effects' (Fig. 3.5b). It is assumed that if more than 50% of a wetland lies within the area experiencing direct effects, the original functions of the area outside the zone of direct effects will be severely degraded or completely lost as well. Thus, this scenario considers effects on the functioning of wetlands partially intersecting the zone of direct effects.

- **Scenario 3:** Mitigation is prescribed for all wetlands identified in scenario 2, plus all additional wetlands ≤ 2.0 ha that intersect or overlap with the 'zone of direct effects' (Fig. 3.5c). This scenario acknowledges that any sort of impact to very small wetlands will greatly alter the functioning of the entire wetland.

- **Scenario 4:** Mitigation is prescribed for all wetlands within the 500 m study area buffer that intersect or overlap the zone of direct effects (the ROW buffer) (Fig. 3.5d). This scenario takes into account the potential effect that connectivity may play in distributing negative effects originating from development impacts occurring within the zone of direct effects to remote locations in the zone of indirect effects. Only the functioning of wetlands completely within the zone of direct effects are at more risk for experiencing potentially negative effects than those wetlands exhibiting connectivity to directly affected wetlands.

- **Scenario 5:** Mitigation is prescribed for all wetland area within the 500 m study area buffer (Fig. 3.5e). Under this scenario there is a marked increase in the total area of wetlands identified, and not all identified wetlands may actually experience *significant* negative effects (e.g. isolated wetlands located far from where actual surface disturbance is taking place, or those wetlands for which only a very small portion of their total area lies in the zone of direct effects). However, based on literature by Forman and Deblinger (2000), Findlay and Bourdages (2000), and Houlahan *et al*. (2006), all wetlands identified have *potential* of experiencing function-altering effects.

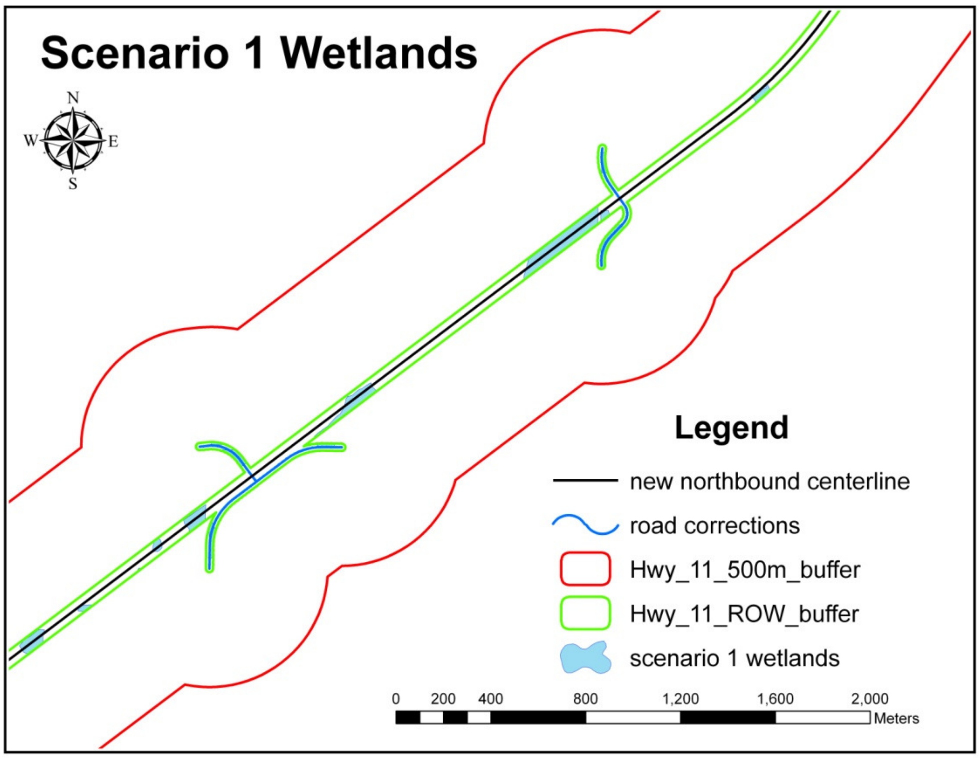


Figure 3.5a Wetlands mitigation scenario 1

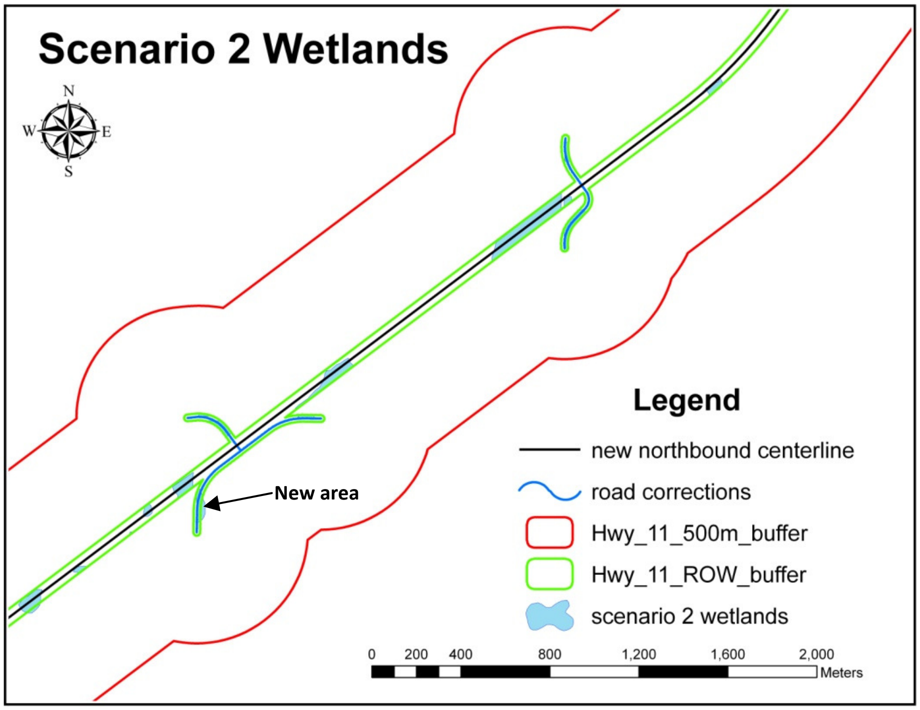


Figure 3.5b Wetland mitigation scenario 2

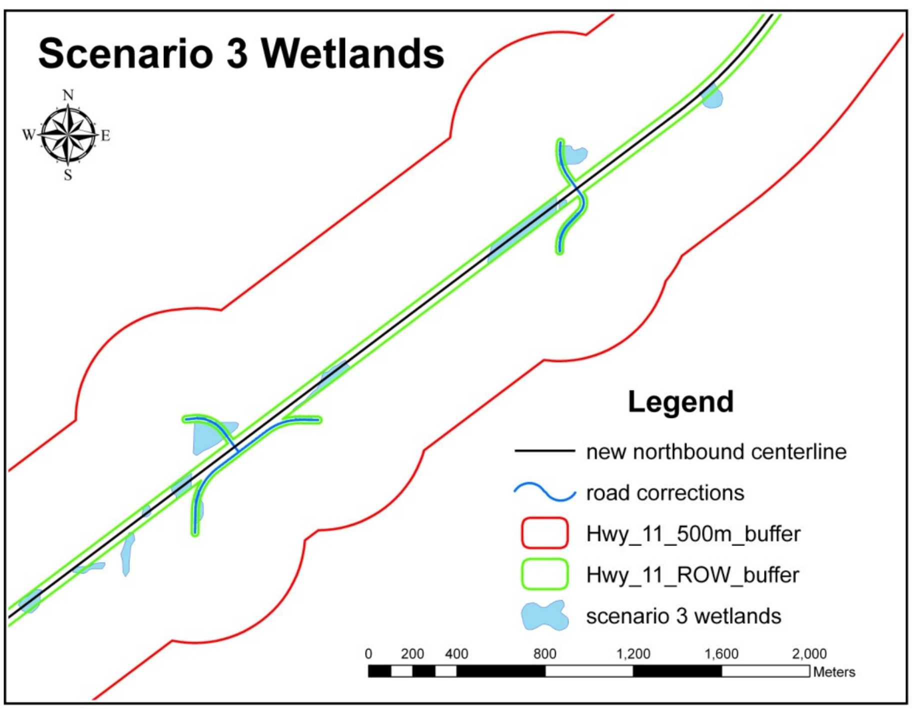


Figure 3.5c Wetland mitigation scenario 3

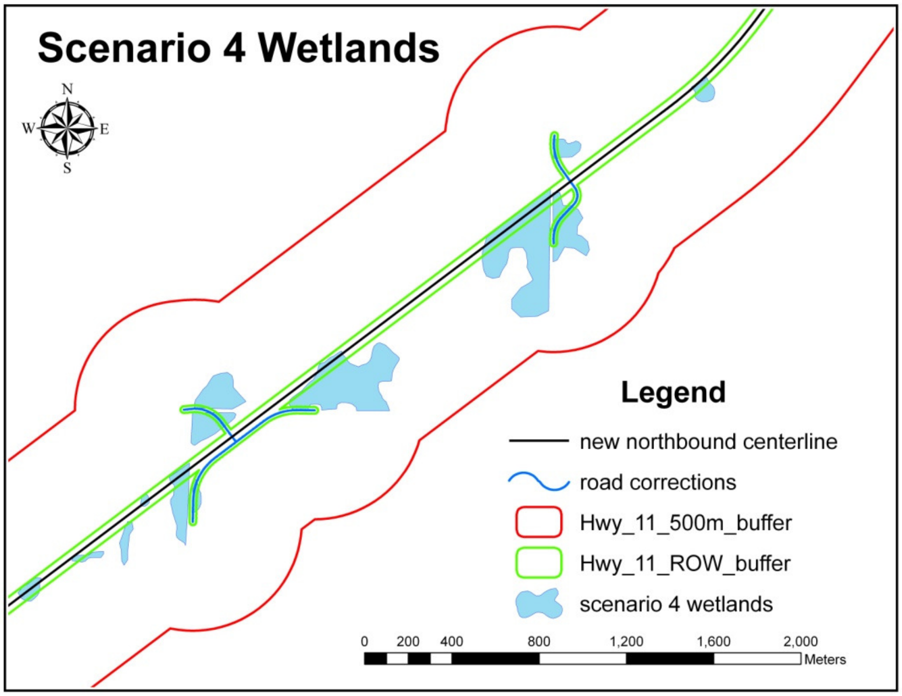


Figure 3.5d Wetland mitigation scenario 4

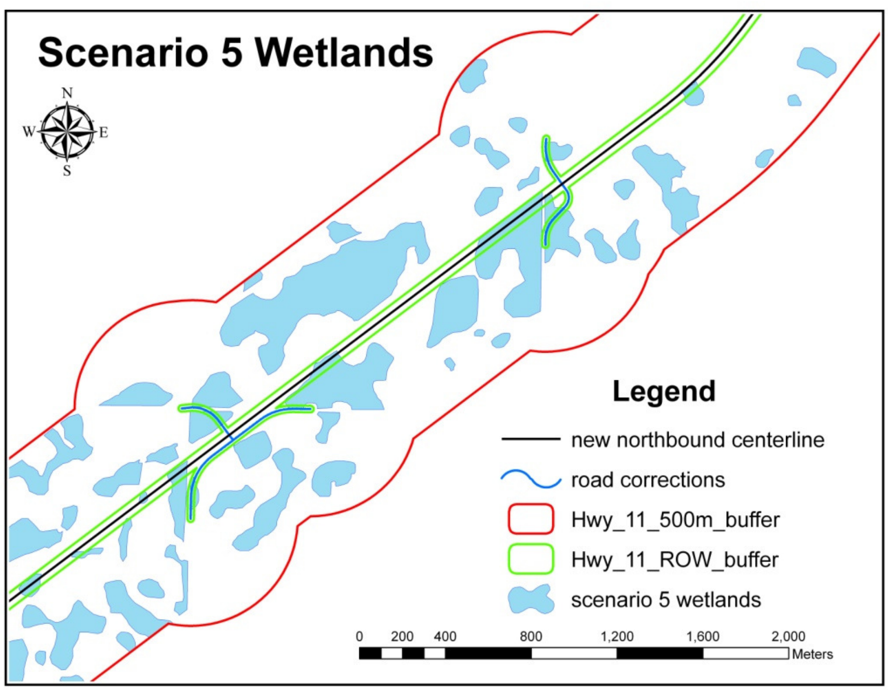


Figure 3.5e Wetland mitigation scenario 5

3.4 Analysis of Wetland Mitigation Scenarios

The final step in the assessment methodology requires a decision to be made regarding the level of mitigation to be undertaken (i.e. choice of a mitigation scenario for cumulative effects). The Analytic Hierarchy Process (AHP) (Satty, 1987), a form of multi-criteria analysis, was used to assess wetland mitigation scenarios on the basis of a set of evaluation criteria, using a panel of experts (see Lahdelma *et al*., 2000).

The AHP generates a ranking of importance or preference amongst a set of alternative attributes through pair-wise comparison of each attribute. Using a matrix table, each attribute is compared, pair-wise, to each other by first making a decision on which is more important in the decision making process, and then ranking that importance on a nine-point reciprocal scale, ranging from equal importance (1), to extremely more important (9), to extremely less important (¼). Following the completion of all individual paired comparisons, eigenvectors are calculated to represent the priority weight or relative importance of alternative attributes (see Noble and Storey, 2001). Tabulation of all individual paired-comparisons combined produces a relative ranking of preference amongst alternatives. Of the many approaches available for the assignment of priority weights, Voogd (1983) recommends Saaty's pairwise comparison approach because panelists are only asked to compare two attributes at once.

The AHP is an excellent tool for the selection of a preferred mitigation option as it produces outcomes based on each individual's results, yet is free of arbitrarily-made decisions, personal bias, and subjectivity (Goyal and Desphande, 2001). For example, the choices individuals make between individual paired-comparisons generate results that may be different than if the individual were to simply make an arbitrary decision on preferred choice of mitigation scenario. It is the process of making small individual choices between paired-comparisons which generates a final overall choice, rather than the participant be forced into 'blindly' making a one-time overall decision. In this way, the decision-making process becomes an objectively-driven systematic approach rather than a subjectively made choice.

3.4.1 Expert Assessment Panel

Following Noble's (2004) approach to the multi-criteria analysis of Canadian energy futures, an expert panel was used for the AHP analysis of mitigation scenarios. The panel consisted of a group of individuals identified as having a background in wetlands, mitigation, resource management, engineering, environmental policy analysis, environmental consulting, and/or environmental assessment. Participants were identified using the snow ball sampling technique, starting with those experts directly involved in the Highway 11 North project and expanding out from there. The purpose of this type of participant identification was to 'cast a broad net' and capture the opinions of a wide array of experts that either directly or indirectly, are involved with wetlands mitigation. Following initial contact via telephone, and in some cases email, an email-out exercise was sent to 50 participants. A total of 26 responses were received and analyzed. The final composition of participants consisted primarily of individuals involved in wetland conservation, including government and non-profit groups (see Table 3.3).

Table 3.3 Break-down of expert panel participant occupations

	Government	Non-Government
# of exercises sent out	28	22
# of exercise responses received	11	15

3.4.2 Expert-based Assessment Process

Using Noble's (2004) approach as a template, the assessment process consisted of two parts, each utilizing the paired-comparison technique (see Saaty, 2008). Participants were first asked to complete an assessment matrix consisting of six mitigation evaluation criteria by comparing each criterion to one another based on their relative importance in making decisions about wetland mitigation. The criteria were identified based on a set of factors that have been considered influential on the choice of mitigation in previous cases of wetlands mitigation (Ducks Unlimited Canada, Head of SK. Wetland Restoration, personal communication, 2009), and are based on minimizing or maximizing conditions as follows:

- *Minimizing Financial Cost of Implementation (C_1):* Total monetary cost of carrying out a specific mitigation scenario/plan, including labour, land acquisition, and equipment/construction costs.
- *Maximizing Compliance with a 'No-net-loss' Policy (C_2):* Ability of a specific mitigation scenario/plan to account for the *total* loss of all wetland *function(s)* (e.g. flood water control, ground water storage and filtration, protection of biodiversity, nitrogen and phosphorus sinks) that were provided by the original wetlands and lost due to the development project.
- *Minimizing Technical Complexity (C_3):* The engineering or technical ease and practicality associated with the actual process of implementing a specific mitigation scenario/plan. In other words, the technical ease of performing mitigation for all the wetlands identified/considered within a specific scenario or plan.

- *Maximizing Consideration of Cumulative Effects (C_4):* Ability of a specific mitigation scenario/plan to ensure the sustainability of wetlands in the project environment by fully accounting for cumulative environment effects (both direct effects, such as grading and infilling of wetlands in a highway right-of-way, and indirect effects, such as change in chemical composition from road salt of adjacent wetlands), including also effects from other non-project-related stress (such as landowner drainage into drainage ditches newly formed by a project development).
- *Minimizing Administrative Complexity (C_5):* Ability of a specific mitigation scenario/plan to be carried out, from the planning phase to the actual in-field implementation, with minimum administrative complexity (e.g. minimizing permit requirements, minimizing complexity surrounding land ownership and access, minimizing number of involved organizations and consultations).
- *Maximizing Public Acceptance (C_6):* Degree to which a specific mitigation scenario/plan is likely to be perceived by the public as satisfactorily 'making-up' for the adverse cumulative effects of the proposed development.

The criteria were evaluated by the expert panel using the following AHP scale (based on Saaty, 2008) (see Fig. 3.6):

Relative importance of the selected criterion '*i*' relative to criterion '*j*':

9 = the criterion is *extremely* more important
8
7 = the criterion is *strongly* more important
6
5 = the criterion is more important
4
3 = the criterion is *slightly* more important
2
1 = the two criteria are of equal importance
* 2, 4, 6, and 8 are 'intermediate' values and can also be used in the rating

	C_1 Cost of implementation	*C_2 Compliance with no net loss policy*	*C_3 Minimizing technical complexity*	*C_4 Consideration of cumulative effects*	*C_5 Minimizing administrative complexity*	*C_6 Public acceptability*
C_1 Cost of implementation		C_1 ☐ ___9___ C_2 ☑	C_1 ☑ ___5__ C_3 ☐	C_1 ☐ ___9___ C_4 ☑	C_1 ☑ ___5__ C_5 ☐	C_1 ☐ ___5__ C_6 ☑
C_2 Compliance with no net loss policy			C_2 ☑ ___9__ C_3 ☐	C_2 ☐ ____7__ C_4 ☑	C_2 ☑ ___9__ C_5 ☐	C_2 ☑ ___9__ C_6 ☐
C_3 Minimizing technical complexity				C_3 ☐ ___9___ C_4 ☑	C_3 ☐ ___1__ C_5 ☐	C_3 ☐ ___7__ C_6 ☑
C_4 Consideration of cumulative effects					C_4 ☑ ___9__ C_5 ☐	C_4 ☑ ___9__ C_6 ☐
C_5 Minimizing administrative complexity						C_5 ☐ ___7__ C_6 ☑
C_6 Public acceptability						

Figure 3.6 Example of a paired-comparison matrix for mitigation evaluation criteria

In the second part of the exercise, participants were presented with the five mitigation scenarios outlined above and asked to evaluate those scenarios based on the criteria, using the same AHP pair-wise process. Participants compared each scenario to every other scenario, pair-wise, based on the ability of that scenario to meet each of the minimizing or maximizing criteria. Comparisons between scenarios were performed using the following rating scale (see Fig. 3.7):

> Relative preference for/ ability of scenario '*x*' to meet the specified criterion '*i*', when compared to scenario '*y*':
>
> 9 = the scenario is *extremely* preferred
> 8
> 7 = the scenario is *strongly* more preferred
> 6
> 5 = the scenario is more preferred
> 4
> 3 = the scenario is *slightly* more preferred

2
1 = the two scenarios are of equal preference

* 2, 4, 6, and 8 are 'intermediate' values and can also be used in the rating

	Scenario $_1$	Scenario $_2$	Scenario $_3$	Scenario $_4$	Scenario $_5$
Scenario$_1$		S_1 ☐ __3____ S_2 ☑	S_1 ☐ ___5___ S_3 ☑	S_1 ☐ ___6___ S_4 ☑	S_1 ☐ ___9___ S_5 ☑
Scenario $_2$			S_2 ☐ ___4___ S_3 ☑	S_2 ☐ ___7___ S_4 ☑	S_2 ☐ ___9___ S_5 ☑
Scenario $_3$				S_3 ☐ ___5___ S_4 ☑	S_3 ☐ ___9___ S_5 ☑
Scenario $_4$					S_4 ☐ ___9___ S_5 ☑
Scenario $_5$					

Figure 3.7 Example of scenario preferences based on consideration of cumulative effects (*C_4*)

To identify a preferred mitigation scenario, a multi-criteria evaluation (MCE) of individual participants' assessment results was performed using Expert Choice© multi-criteria decision support software. This generated criteria weights and scenario assessment scores for each participant. Due in part to the small, non-random sample, individual results were aggregated and the median values used for analysis of the evaluation criteria and mitigation scenarios. Results from the MCE were evaluated using exploratory data analysis (EDA) techniques using SPSS© software, including concordance analysis, scaling based on Euclidean distances, and Tukey's hinges to generate confidence intervals about the median (see Noble, 2004; Noble and Christmas, 2008). The median and 95% confidence interval using Tukey's hinges is a type of EDA measure that does not make inferences regarding the size of the population sampled nor the sampling scheme used (see Velleman and Hoaglin, 1981).

CHAPTER 4

ASSESSMENT RESULTS

4.0 Introduction

This chapter presents the results of the thesis research. First the results of the wetland cumulative effects baseline analysis are presented, which includes the total potentially direct and indirectly affected wetlands along with the number and area of wetlands captured by each mitigation scenario. Second, the results of the expert-based analysis of alternative mitigation scenarios are described, including the paired-comparison matrix analysis for mitigation criteria evaluation and preferred mitigation scenarios, along with analysis of the robustness of the scenario rankings and sensitivity to changes in criteria importance.

4.1 Wetlands Baseline and Potential for Cumulative Effects

The baseline for the wetlands cumulative effects assessment consisted of a total of 458 wetlands (1,115 ha) located within the 500 m assessment area; those wetlands considered to be potentially affected by the Highway 11 North twinning development (Table 4.1), of which 244 (more than 50%) were < 1.0 ha in size (Fig. 4.1). Of the 458 wetlands identified, 334 (approximately 70%) were < 2.0 ha, a result typical of a prairie landscape dominated by small ‘pot-hole’ wetlands.

Table 4.1 Digitization summary statistics

Total Number of Wetlands Digitized	458
Total Area	1,115 ha.
Average Size	2.43 ha.
Maximum Size	125.72 ha.
Minimum Size	0.02 ha.

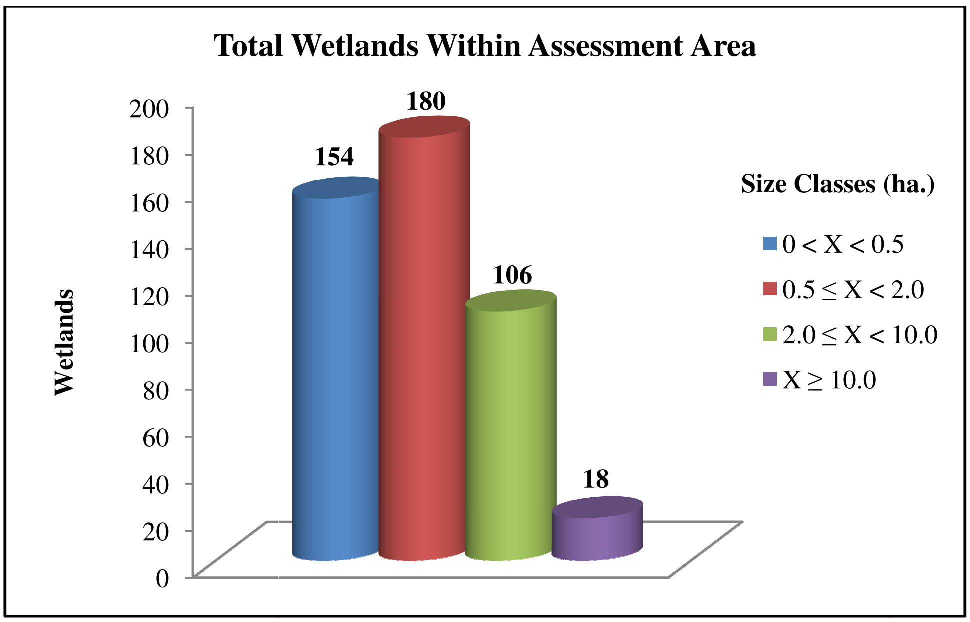


Figure 4.1 Size classes of wetlands within the assessment area

In general, the Prince Albert precipitation data shows higher levels of precipitation than recorded in Saskatoon (see Table 3.1); an aspect that may contribute to the fact that approximately half of all wetlands digitized are in the northern-most 30 km of the 110 km highway to be twinned (see Fig. 4.2).

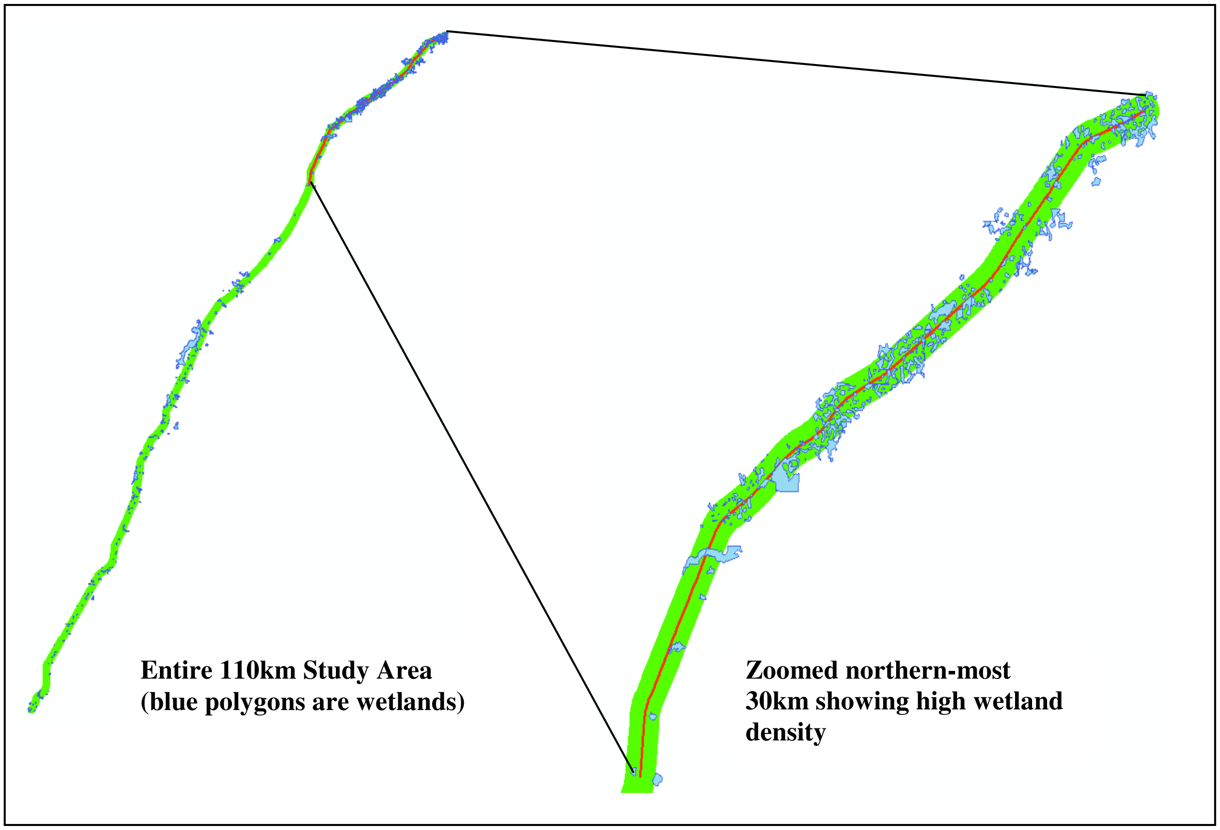


Figure 4.2 Density of wetlands in the northern portion of the study area
*** Blue area- wetlands, red line- highway centerline, green area- study area**

Of the total 458 wetlands (1,115 ha) that formed the baseline for the cumulative effects assessment, a total 50.08 ha of wetlands (portions of 123 wetlands, of which only 10 were completely within the ROW) were located in the zone of direct effects (see Fig. 4.3); that area denoted by the 31 m highway ROW and 15 m road corrections ROW combined, and for which it is assumed that complete loss of wetland habitat and function occurs. A total of 1,064.92 ha of wetlands (448 wetlands) were located in the zone of indirect effects (see Fig. 4.3); that area outside the zone of direct effects extending up to the 500 m assessment area boundary, and for which it is assumed that wetlands will experience some sort of functional loss. The combined direct and indirectly affected wetland area equals a cumulative, or total affected wetland area, of 1,115 ha. Given the current approach to wetlands mitigation assessment (i.e. considering only the wetland area directly within the *highway* ROW) (e.g. Golder, 2006), only 45.20 ha (101 wetlands) would be affected by the twinning development and require mitigation.

Total area of wetlands identified as being affected in each mitigation scenario (see Section 3.3) were as follows (see Fig. 4.4a to e):

- Scenario 1: 50.08 ha (123 wetlands)
- Scenario 2: 60.04 ha (123 wetlands)
- Scenario 3: 95.30 ha (123 wetlands)
- Scenario 4: 453.95 ha (123 wetlands)
- Scenario 5: 1,115 ha (458 wetlands)

The reason why the first four scenarios have different total affected area yet all include the same number of wetlands is that each of the scenarios identifies the same wetlands but progressively include more wetland area than the previous scenario. In other words, scenarios 1 to 4 each identify only the wetlands overlapping with the zone of direct effects, but each scenario includes a greater proportion of the overlap area of those wetlands than the previous scenario. The total area and number of wetlands increases substantially in scenario 5, because in addition to the wetlands overlapping with the zone of direct effects this scenario also includes those isolated wetlands in the zone of indirect effects.

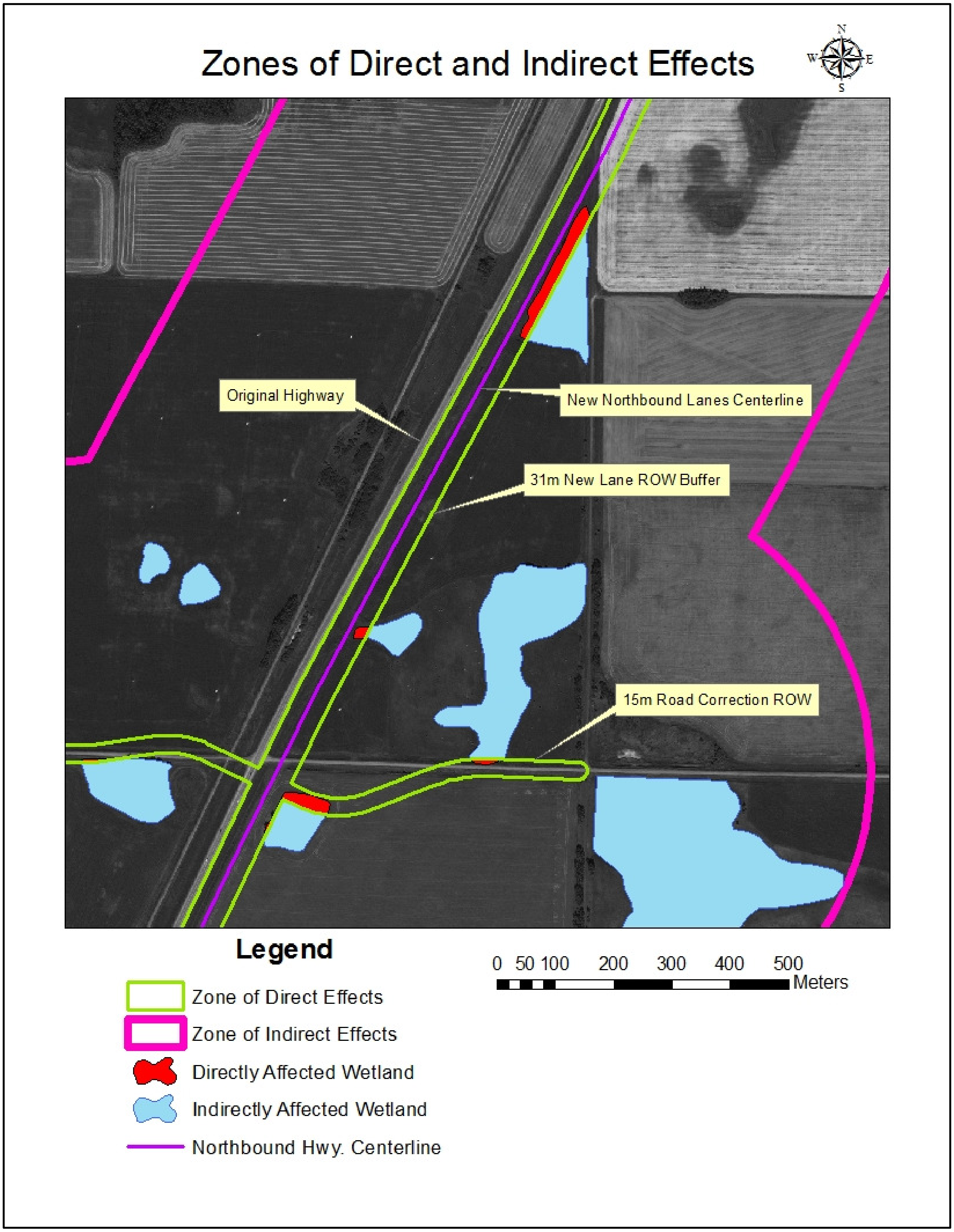


Figure 4.3 Example of potentially direct and indirectly affected wetlands

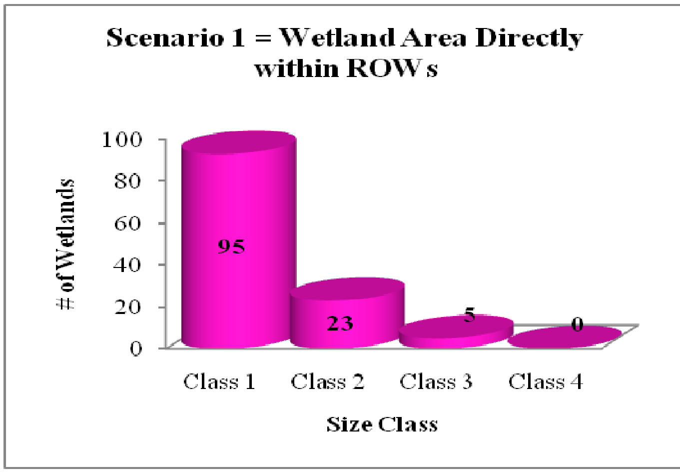


Figure 4.4a Wetland size classes in scenario 1

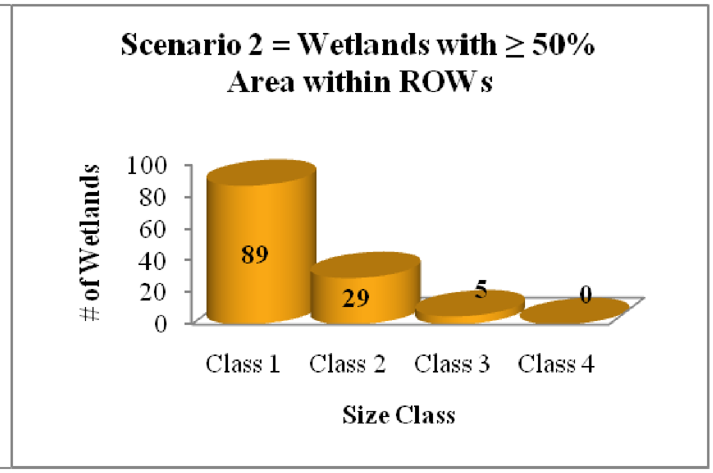


Figure 4.4b Wetland size classes in scenario 2

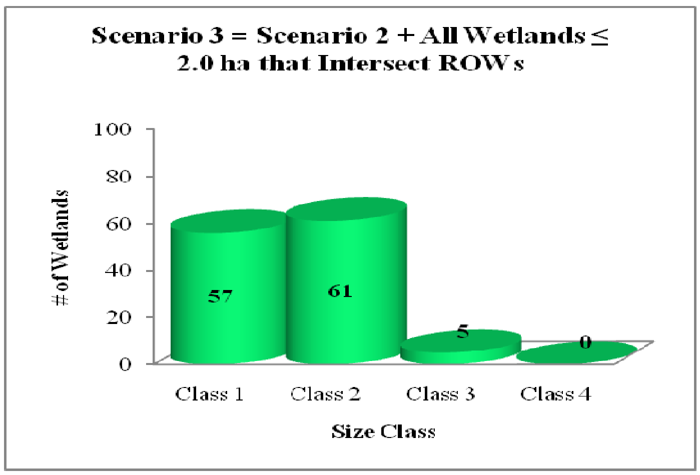


Figure 4.4c Wetland size classes in scenario 3

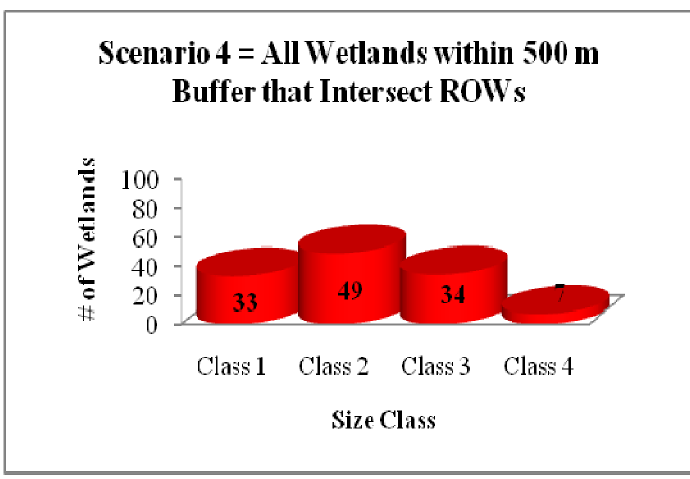


Figure 4.4d Wetland size classes in scenario 4

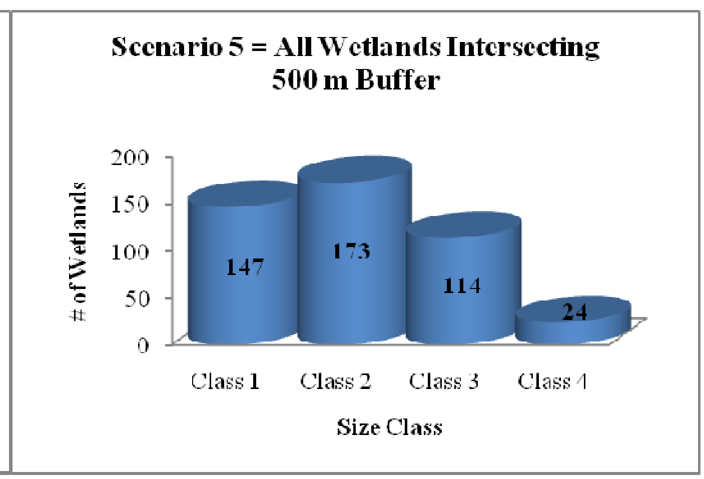


Figure 4.4e Wetland size classes in scenario 5

4.2 Mitigation Scenario Assessment Results

The result of the AHP is the generation of an assessment score or weight for each of the variables included in the matrix, which provides a means of making comparisons between the importance of each criteria and relative preference for each scenario. The higher the value, the more important is that criterion or more preferred is that scenario relative to all other competing criteria or scenarios (see Noble and Christmas, 2008).

4.2.1 Evaluation of Criteria Weights

The relative importance of evaluation criteria was determined by assigning weights to the criteria through the use of the AHP in the first part of the expert survey exercise. Weights were aggregated for each of the six evaluation criteria and the median weights calculated (Fig. 4.5).

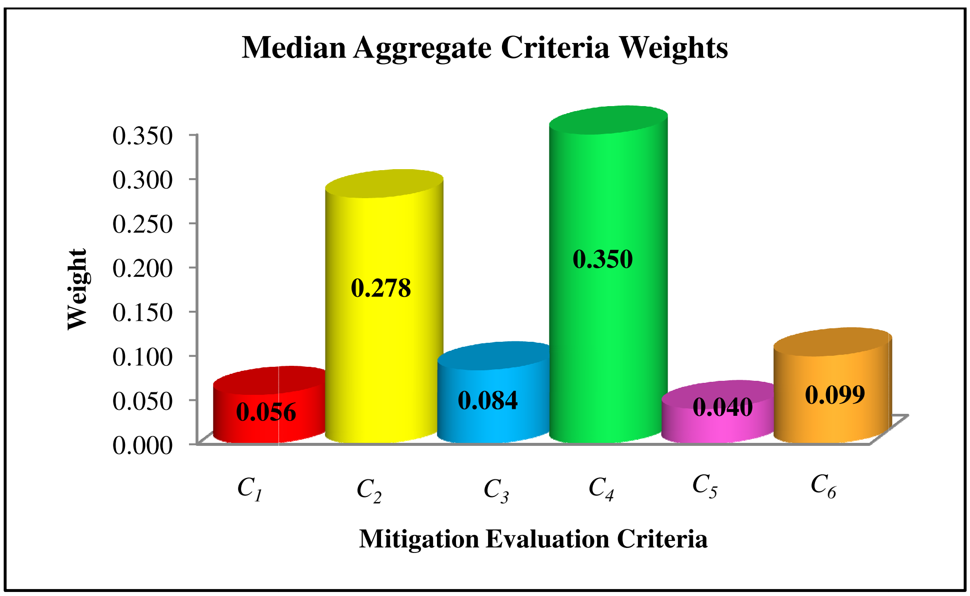


Figure 4.5 Median aggregate results of mitigation criteria weighting

Conventional box-plot statistics were used to identify the median, the data spread, and the skewness of the aggregate criteria weights (Fig. 4.6). The AHP revealed that criterion C_4, *Maximizing Consideration of Cumulative Effects*, is the most important of the six criteria to consider when making decisions about wetland mitigation. This was followed by criterion C_2, *Maximizing Compliance with a 'No-net-loss' Policy*.

Tukey's hinges and the median criteria weights were used to explore the aggregate dataset for significant differences, using a 95% confidence interval (CI) for the median (Table 4.2). What this shows is that for each criterion, one can be 95% confident that the aggregate median criterion value falls within the respective weight interval. Overlap of one criterion's 95% CI with that of another criterion denotes no significance difference between criteria (Fig. 4.7). This means that these criteria are similar and maximization or minimization of one would usually mean maximization or minimization of the other. Table 4.3 indicates significant differences between criteria. Results of a Mann Whitney U statistical test for differences confirms the similarity amongst criteria, revealing that criteria C_2 and C_4 are not statistically different (Mann Whitney U = 242.000, p = 0.079), as are criteria C_1 and C_5 (Mann Whitney U = 291.500, p = 0.395) and criteria 3 and 6 (Mann Whitney U = 309.000, p = 0.595).

Consensus amongst participants in terms of the importance of assessment criteria is indicated by the interval between the upper and lower fences of the 95% CI for the medians. The smaller the interval, the more consensus on the relative importance of a particular criterion in wetland mitigation decision-making (see Table 4.2). Similarly, this consensus, which is ultimately the spread of values around the median, can be graphically portrayed, as indicated in Figure 4.7. The smaller the confidence interval, the more tightly values are grouped around the median value; an indication of low deviation (high consensus) in the weights assigned to that particular criterion. Although weighted the most important overall, criterion C_4, *Maximizing Consideration of Cumulative Effects,* also had the most deviation (least consensus) in individual weightings. Criterion C_5, *Minimizing Administrative Complexity*, which was viewed as the least important criteria amongst participants (i.e. weighted the least) had the least amount of deviation (highest consensus) amongst participant's weightings.

Table 4.2 Median criteria weights and 95% CI, n=26

Criteria	95 % Confidence Interval[a]			
	Lower Fence	Median	Upper Fence	Interval
C_1 Financial Cost	0.042	0.056	0.069	0.028
C_2 No-Net-Loss Compliance	0.227	0.278	0.329	0.103
C_3 Technical Complexity	0.068	0.084	0.099	0.030
C_4 Cumulative Effects Consideration	0.289	0.350	0.411	0.121
C_5 Administrative Complexity	0.027	0.040	0.052	0.025
C_6 Public Acceptance	0.071	0.099	0.127	0.056

[a] The 95% confidence interval for the median is a distribution free statistic. It is calculated as follows: Upper and lower fence = median±(1.58 x (H-spread)/√*n*). Where the H-spread is the difference between Tukey's upper and lower hinges, as determined from the box and whisker plot, and gives the range covered by the middle half of the data (approx. the 25th and 75th percentile) (Velleman and Hoaglin, 1981).

Table 4.3 Paired differences, Tukey's hinges test for significance between criteria*

	C_1	C_2	C_3	C_4	C_5	C_6
C_1		<	<	<	/	<
C_2			>	/	>	>
C_3				<	>	/
C_4					>	>
C_5						<
C_6						

*** Where criterion *i* (row) is significantly different than criterion *j* (column) as expressed by:**
> = criterion *i* significantly greater than *j*
< = criterion *i* significantly less than *j*
/ = cannot be said that criterion *i* and *j* are different

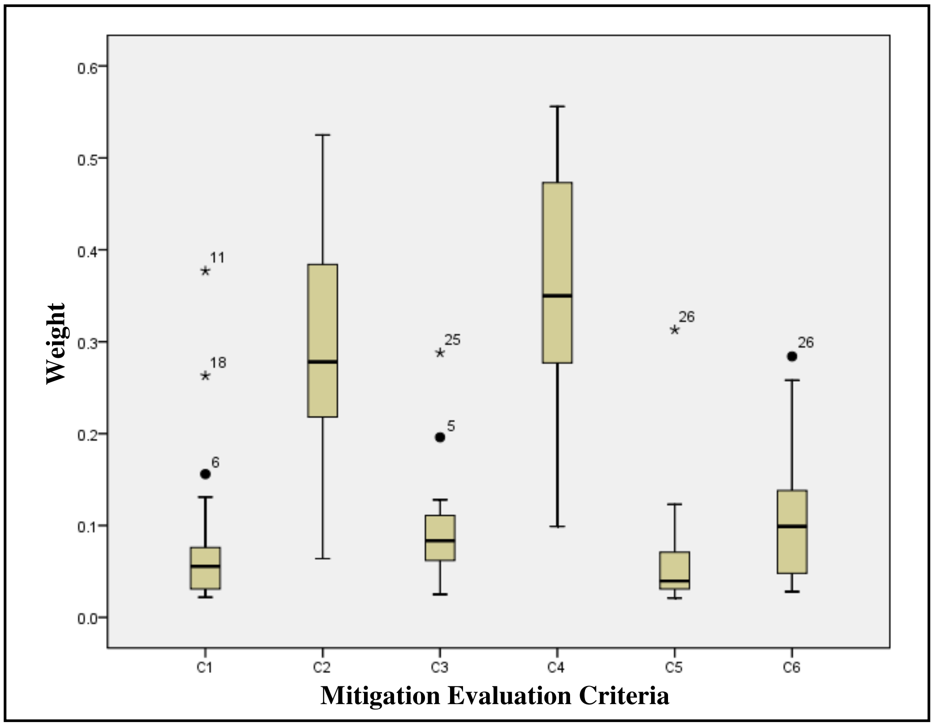


Figure 4.6 Box plot of evaluation criteria and associated weights
*** The black lines represent the medians, the box represents the middle 50% of the data or the interquartile range (IQR), the upper hinge indicates the 75th percentile, and the lower hinge indicates the 25th percentile. The circles are data outliers (more than 1.5 times the IQR from either end of the box) and the stars are extreme outliers (more than 3 times the IQR from either end of the box).**

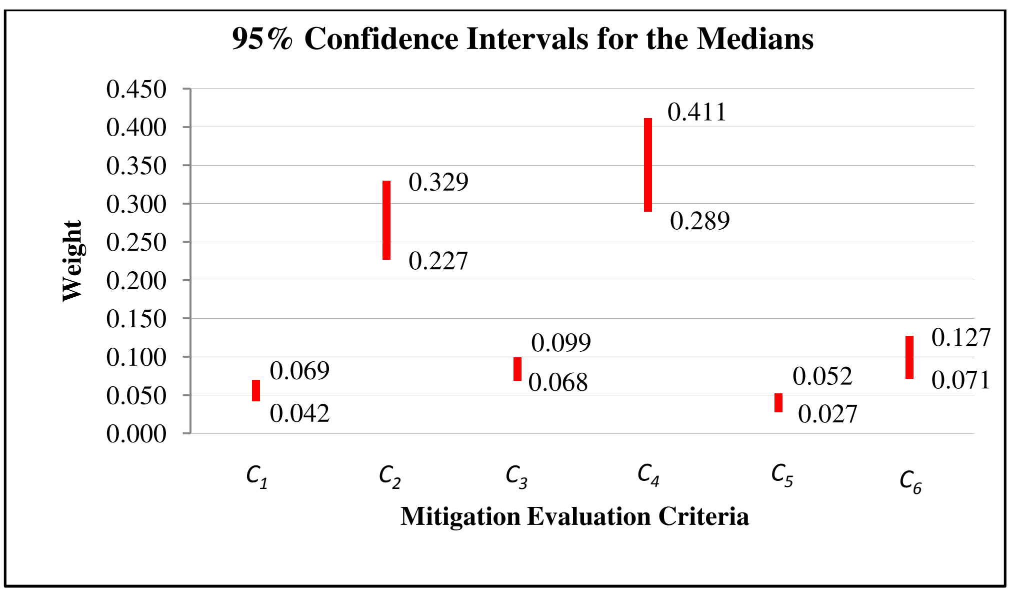


Figure 4.7 95% Confidence intervals around the median aggregate criteria weights
*** Confidence intervals are indicated by the bars and the medians are represented by the horizontal black lines. The values shown indicate the upper and lower fence for each median.**
Overlap of confidence intervals indicates statistical similarity.

4.2.2 Wetland Mitigation Preferences: Unweighted

The aggregate, median results of the unweighted assessment scores for mitigation scenarios are summarized in Table 4.4. This ranking of scenarios is independent of the relative importance of each criterion in mitigation decision-making (i.e. criterion weights). The ranking of mitigation scenarios in terms of overall optimization of all six evaluation criteria simultaneously is as follows: *scenario 5* > *scenario 1* > *scenario 4* > *scenario 2* > *scenario 3* (where > indicates preference). Of the six evaluation criteria on which the scenarios were assessed, three involved criteria maximization (C_2, C_4, and C_6), and three involved criteria minimization (C_1, C_3, and C_5). The most liberal mitigation scenario, scenario 5, outranks all other scenarios on C_2, C_4, and C_6, while the most conservative mitigation scenario, scenario 1, outranked all other scenarios on the basis of C_1, C_3, and C_5.

Table 4.4 Aggregate, median assessment scores for unweighted mitigation scenarios

	Scenario1	**Scenario2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
C1	0.479	0.261	0.141	0.067	0.032
C2	0.030	0.052	0.099	0.251	0.570
C3	0.420	0.267	0.166	0.081	0.033
C4	0.033	0.051	0.089	0.242	0.597
C5	0.395	0.271	0.161	0.095	0.034
C6	0.042	0.066	0.125	0.257	0.494
Sum	**1.399**	**0.968**	**0.781**	**0.993**	**1.760**
Rank	**2**	**4**	**5**	**3**	**1**

4.2.3 Wetland Mitigation Preferences: Weighted

Multiplying the median, unweighted assessment scores by the median criteria weights generates weighted assessment scores, representing the preferred choice of mitigation scenario given the relative importance of the evaluation criteria. Results of weight application to scenario assessment scores are shown in Table 4.5. The ranking of preferred scenarios changes with the assignment of weights. For example, Figure 4.8 shows the comparison between unweighted and weighted scenario scores, scaled using a standardized scaling parameter of:

$$i = \frac{(i - i_{min})}{(i_{max} - i_{min})} \quad \textbf{(Equation 4.1)}$$

Where: i = scaled assessment score

i_{min} = minimum assessment score

i_{max} = maximum assessment score

The result is a ranking of scenarios where the preferred scenario is always '1' and the least preferred scenario is always '0'.

The rankings of scenarios 1 and 4, and scenarios 2 and 3, reversed when the criterion weights were applied. The reason for the reversal in preferences between scenarios 1 and 4 is due to the conservative approach to mitigation in scenario 1; scenario 1 scores poorly in terms of optimizing the two most heavily weighted evaluation criteria - *Maximizing Compliance with a 'No-net-loss' Policy* (C_2), and *Maximizing Consideration of Cumulative Effects* (C_4); whereas scenario 4 scores much better on these criteria. Similar logic can explain the rank reversal between scenarios 2 and 3. Scenario 5 remained the most preferred mitigation scenario in both unweighted and weighted cases.

Table 4.5 Aggregate, median assessment scores for weighted mitigation scenarios

	Scenario1	**Scenario2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
C1	0.027	0.014	0.008	0.004	0.002
C2	0.008	0.014	0.028	0.070	0.158
C3	0.035	0.022	0.014	0.007	0.003
C4	0.012	0.018	0.031	0.085	0.209
C5	0.016	0.011	0.006	0.004	0.001
C6	0.004	0.007	0.012	0.025	0.049
Sum	**0.101**	**0.086**	**0.099**	**0.194**	**0.422**
Rank	**3**	**5**	**4**	**2**	**1**

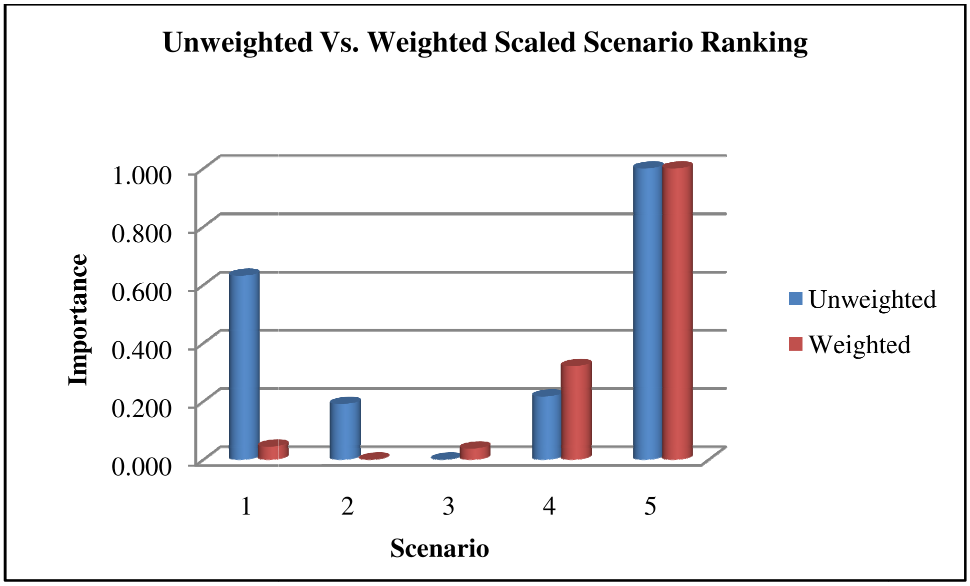


Figure 4.8 Changes in unweighted vs. weighted ranking of preferred mitigation scenarios

4.2.4 Confirmatory Analysis

Given the nature of the AHP with its many scenarios and multiple criteria, there is a need to determine the preferred ranking of scenarios based on an outranking relationship of all scenario-criterion relationships considered simultaneously (see Noble, 2002a). Concordance analysis provides for such an outranking relationship, allowing all scenarios to be compared to one-another on the basis of the set of criteria weights, from which a final assessment score and outranking relationship can be derived for each scenario (see Voogd, 1983). The outranking relationship for two scenarios *i* and *j* can be defined as:

- the 'concordance set' C(*ij*) is all criteria for which scenario *i* is preferred to scenario *j*
- the 'discordance set' D(*ij*) is all criteria for which scenario *j* is preferred to scenario *i*
- the tie set T(*ij*), where scenario *i* is equally preferred to scenario *j*

Or, $c_{ij} = \left[\sum_{j\ C(ij')} W_j + \tfrac{1}{2} \sum_{j\ T(ij')} W_j \right] \Big/ \left[\sum_{j=1}^{n} W_j \right]$ **(Equation 4.2)**

Where: *W* equals the weighted impact score (based on Voogd 1983; and Noble 2002b).

The concordance analysis was used to determine the weighted ranking of each scenario and to derive a relative measure of preference of one scenario over all others. Concordance results for the ranking of mitigation scenarios are shown in Table 4.6. This ranking structure is a result of the lesser scenario always being preferred to the greater scenario for criteria C_1, C_3, and C_5 (e.g. Scenario 1 is preferred over Scenario 2, Scenario 2 is preferred over Scenario 3 and so on) whereas the greater scenario is always preferred over the lesser scenario for criteria C_2, C_4, and C_6. This is because criteria C_1, C_3, and C_5 are minimizing criteria. For example, for C_1, C_3, and C_5 the lesser scenario that minimizes each criterion (i.e. the scenario that includes less affected wetland) is always more preferred in the pair-wise comparisons. Criteria C_2, C_4, and C_6 however, are maximizing criteria. For C_2, C_4, and C_6 the greater scenario that maximizes each criterion (i.e. the scenario that includes more affected wetland) is always more preferred in the pair-wise comparisons).

Comparing concordance results with the weighted AHP results (see Table 4.5) indicates that the ranking of scenarios is consistent for scenarios 4 and 5, but changes for scenarios 1, 2, and 3. At first glance, this change in ranking may seem to indicate discrepancy between the AHP and Concordance Analysis. However, once EDA was used to analyze this difference in results, the cause of the discrepancy was revealed. Performing a Mann Whitney statistical test for differences between weighted mitigation scenarios indicated that scenarios 1, 2, and 3 are not statistically different (see Table 4.7). This is attributed to the similarity of the three scenarios' weighted assessment scores (see Table 4.5). Thus, the ranking of mitigation scenarios can be summarized as: *scenario 5 > scenario 4 > scenario 3 I scenario 2 I scenario 1* (Where: > denotes preference, and *I* denotes indifference between scenarios).

Table 4.6 Concordance results for ranking of preferred mitigation scenario

	Scenario1	Scenario2	Scenario 3	Scenario 4	Scenario 5	Row Sum	Rank
Scenario1		0.197	0.197	0.197	0.197	0.789	**5**
Scenario2	0.803		0.197	0.197	0.197	1.394	**4**
Scenario 3	0.803	0.803		0.197	0.197	2.000	**3**
Scenario 4	0.803	0.803	0.803		0.197	2.606	**2**
Scenario 5	0.803	0.803	0.803	0.803		3.211	**1**

Table 4.7 Mann Whitney test for differences between weighted mitigation scenarios

Scenario 1 and Scenario 2	Mann Whitney U = 12055.000,p = 0.887
Scenario 1 and Scenario 3	Mann Whitney U = 11045.500,p = 0.159
Scenario 2 and Scenario 3	Mann Whitney U = 11368.000,p = 0.315

4.2.5 Sensitivity Analysis

Before generalized conclusions can be drawn from the results, it is important to determine the robustness of the preferred mitigation option and how uncertainties and changing conditions might affect the overall preference structure. For example, the choice of preferred mitigation scenario is dependent on the perceived importance or weighting of the six evaluation criteria. The sensitivity of the ranking of scenarios to uncertainties and changing future conditions or priorities can thus be determined by measuring the effect of alternative weightings of the evaluation criteria on the ranking of mitigation scenarios (see Noble and Christmas, 2008). Sensitivity analysis reveals how sensitive the preferred choice of mitigation is to changes in the importance of the evaluation criteria.

The criteria chosen for testing sensitivity were *Minimizing Financial Cost of Implementation* (C_1), *Maximizing Compliance with a 'No-net-loss' Policy* (C_2), and *Maximizing Consideration of Cumulative Effects* (C_4), as these three criteria are weighted most important from a practical mitigation implementation perspective. However, because criteria C_2 and C_4 are not statistically different, these criteria were manipulated simultaneously, and together can be viewed as a 'maximizing wetland conservation' criterion. Table 4.8 shows the eight different cases of sensitivity analysis that were performed.

Table 4.8 Sensitivity analysis cases

Analysis Case	Description
1	Unweighted Assessment Scores
2	Weighted Assessment Scores
3	50% reduction in C_2 (no-net-loss) and C_4 (cumulative effects) weights
4	50% increase in C_1 (financial cost) weight
5	Double the weight of C_1 weight
6	Triple the weight of C_1 weight
7	75% reduction in C_2 and C_4 weights
8	50% reduction in C_2 and C_4 weights and triple C_1 weight

All cases of scenario preference had scenarios 2 and 3 as the least preferred scenarios (see Fig. 4.9). The reason for this is because these two scenarios fall near the middle of the spectrum of scenarios in terms of the number/area of wetlands identified, which lead them to being neither ranked highly in minimizing criteria C_1, C_3, or C_5 nor maximizing criteria C_2, C_4, or C_6. In most cases of weighted scenario preference (i.e. cases 2-5), scenario 3 was only slightly preferred to scenario 2 (tied in analysis case 3) (see Table 4.9), the reason being that it scored slightly better in terms of criteria C_2 and C_4- the two most weighted criteria. Therefore, it was not until the extreme situations when minimizing financial cost was given far greater importance/weight relative to maximizing wetland conservation (cases 6-8) did scenario 3 replace scenario 2 as the least preferred scenario. The explanation for this reversal is because scenario 2, with its fewer wetlands identified, outscores scenario 3 (which includes more wetlands) in terms of minimizing financial cost of required mitigation (criteria C_1).

Table 4.9 Sensitivity analysis comparison between scenario 2 and 3 normalized weightings

Analysis case	Scenario 2	Scenario 3
1	0.191	0.000
2	0.000	0.038
3	0.000	0.000
4	0.000	0.028
5	0.000	0.019
6	0.002	0.000
7	0.077	0.000
8	0.089	0.000

The results of the sensitivity analysis confirm that the original preference structure of mitigation scenarios is robust. Only after an extreme shift in the original criteria weights did the ranking of preferred scenarios change. From a practical standpoint, minimizing the financial cost of implementing a proposed mitigation action (criteria C_1) and maximizing wetland conservation (criteria C_2 and C_4 combined), are two practical aspects of significant influence on wetlands mitigation planning (Michael Hill- DUC, Head of Wetland Conservation for SK, personal communication). Results of the AHP indicated that C_2 and C_4 were considered the most important aspects (ranked 2nd and 1st, respectively), while C_1 was ranked fifth. From Figure 4.9, it can be seen that not until analysis case 7 and 8, which involved a 75% reduction in C_2 and C_4, followed by a 50% reduction in C_2 and C_4 combined with a threefold increase in C_1 weight, does the ranking of scenarios change from the original weighted ranking of analysis case 2 (scenarios 2 and 3 reversed ranks in analysis case 6, but the difference between the two scenarios was negligible- 2 thousandths difference). This indicates that except in very extreme situations, maximizing wetland conservation should be the number one priority of wetland mitigation regardless of associated financial costs.

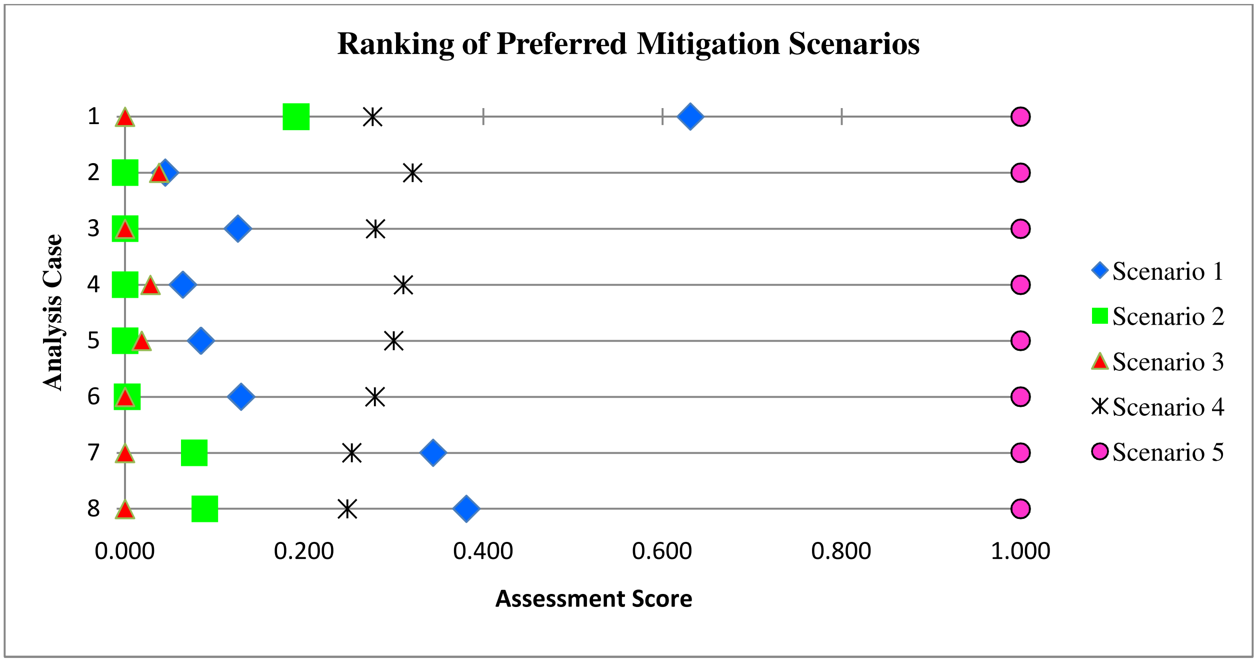


Figure 4.9 Results of sensitivity analysis on ranking of preferred mitigation scenarios

CHAPTER 5
DISCUSSION AND CONCLUSION

5.0 Introduction

Based on an assessment of the Highway 11 North twinning project in Saskatchewan, Canada, this research set out to demonstrate a methodological framework and guidance for the integration of cumulative effects in decision-making for project-based wetland impact mitigation. Loss of Canadian wetlands, particularly on the prairies, and the associated loss and degradation of the many functions and values wetland ecosystems provide, is an ongoing problem. There are constant and consistent messages in the literature on the need to incorporate cumulative effects considerations into the assessment and mitigation of wetland impacts and, in doing so, ensure a no-net-loss of wetland functions (Risser, 1988; Bedford and Preston, 1988; Johnston, 1994; Abbruzzese and Leibowitz, 1997; Cox and Grose, 1998; Bedford, 1999; Tiner, 2005). The current approach to assessing impacts to wetlands, however, is to only consider those wetlands directly affected; often restricting wetlands assessment to only the right of way in the case of highway construction projects (e.g. Golder, 2006). This chapter discusses the implications of the research results for the Highway 11 North twinning development, limitations to the assessment, and the future practice of wetland cumulative effects assessment and mitigation.

5.1 Wetland Baseline Environment and Potential for Cumulative Effects

Although the Highway 11 North development is already partially completed, evaluating the potential cumulative effects of the project is necessary to ensure that appropriate mitigation measures are identified and implemented – especially since no formal EA was required for the majority of the development. A total of 458 wetlands (1,115 ha) were identified to be potentially affected by the Highway 11 North twinning development, of which 244 (more than 50%) were < 1.0 ha in size - wetlands that are often forgotten about in wetland mitigation plans. Such a distribution is typical of a prairie landscape, and indicative of the need for a mitigation approach that does not overlook the cumulative loss of many small wetlands in the assessment and mitigation process. It is the cumulative loss of these many, often small wetlands combined that adds up to a significant loss of overall wetland habitat and functions. The framework developed and demonstrated in this research does not make any bias towards the size of wetlands when making decisions regarding required mitigation. Rather, the focus is on total wetland area within various zones of impact in relation to a project's direct and indirect and induced effects. Regardless of size, all affected wetlands perform important functions and must be mitigated in order to achieve a policy of no-net-loss.

5.2. Wetland Cumulative Effects Mitigation Scenarios

Decision-making for mitigation of the affected wetlands was aided through the use of multiple mitigation scenarios, evaluated by a panel of experts using the AHP. The panel of experts indicated that maximizing wetland conservation should be the priority of wetland mitigation, regardless of associated financial costs (see Fig. 4.9). As such, mitigation scenario 5, the most liberal of the scenarios in terms of wetlands to be included for mitigation, was always far greater preferred than the other scenarios, both in the unweighted and weighted rankings (see Fig. 4.8). In the unweighted rankings, panel members chose scenario 5 as the most preferred scenario, with an assessment score of 1.760. Scenario 1, the most conservative of the scenarios in terms of wetlands to be included for mitigation was ranked second most preferred, with an assessment score of 1.399. This unweighted ranking is indicative of the fact that scenario 5 scored highly in terms of maximizing criteria C_2, C_4, and C_6 while scenario 1 scored highly in terms of minimizing criteria C_1, C_3, and C_5. Next highest ranking was scenario 4, followed by scenario 2, and finally scenario 3, which was the least preferred scenario as it was seen as neither being good at maximizing criteria C_2, C_4, and C_6, nor minimizing criteria C_1, C_3, and C_5 . The fact that more precedence was given to the maximizing criteria (the conservation criteria) over the minimizing criteria (the economic criteria), as evidenced by the most liberal scenario being preferred over the most conservative scenario, alludes to participants' ranking of mitigation criteria importance and the preference structure of the weighted mitigation scenarios.

As a whole, the panel ranked criterion C_2 (no-net-loss) and C_4 (consideration of cumulative effects) much more important than any other criteria (0.278 and 0.350 respectively) (see Fig. 4.5). Because scenario 5 includes all wetland area potentially affected by the twinning development, it accomplishes more than the other scenarios in terms of maximizing these two most important criteria, and was therefore the highest ranking of the weighted scenarios (with an assessment score of 0.422, followed by scenario 4 at 0.194). Criteria C_1 (financial cost), on the other hand, was ranked the fourth most important criterion (0.056) and, as such, caused scenario 1 to be ranked the third most preferred of the weighted scenarios, with an assessment score of 0.101, over four times less than scenario 5.

Results such as these speak to the need to place no-net-loss or wetland conservation in general, as the most important factor in wetland mitigation planning. Such an outcome may not have been the case if participants were simply asked to arbitrarily rank the importance of evaluation criteria. Even though the two 'conservation' criteria were determined by the AHP to be most important, in reality the influence of criteria C_1 (financial cost of mitigation) is often the number one influence on determining the level of mitigation implemented, and its impact on mitigation planning cannot be overlooked. Another factor that cannot be overlooked in such a result is the background of participants. Of the 50 participants initially contacted, all 26 that responded had some sort of background in environmental management, biology, or conservation. Therefore, it should not be surprising that results lean towards wetland conservation as a priority factor in planning for wetland mitigation. It is telling however, that despite the fact those directly involved with wetland mitigation lean strongly towards the option that favors conservation, it is usually the case that overly ambitious conservation plans fall short of achieving their goals. The reason for such a trend can only be speculated, but it is safe to assume that the issue of limited resources will almost always dictate the actual mitigation implemented, regardless of what is proposed.

5.3 Assessment Limitations

The main challenges and limitations in developing a methodological framework and guidance for the integration of cumulative effects in decision-making for project-based wetland impact mitigation is inherent in the design of this framework and others like it. As Abbruzzese and Leibowitz (1997) allude to, any framework designed for time-effective CEA is inherently limited regarding the amount of supporting quantitative data that can be collected and incorporated into its creation. Therefore, assessment must rely more heavily on qualitative analysis and inferences or assumptions for which quantitative data to directly support statements that are being made, does not necessarily exist. This is especially true regarding loss of wetland functions.

Determining the relationship between project impacts and functional loss/degradation to wetlands is very difficult in itself, even when detailed quantitative field studies have been performed (Abbruzzese and Leibowitz, 1997). Therefore, as is the case in many wetland impact studies, the absence of comprehensive quantitative analysis coupled with the complex nature of the functions themselves, limits researchers such as myself to making educated assumptions regarding the indirect effects of road development on wetland function.

Other limitations of the framework are found in the form of the data used. In order to achieve the highest possible accuracy for the quantification of affected wetlands within the study site, digital orthophotography would be recommended (Lyle Boychuk- DUC Western GIS Manager, personal communication, Oct. 30, 2007). The inability to view satellite imagery in stereo (3-D) makes classification more difficult/less accurate compared to stereo air photo (orthophoto) classification that uses elevation to greatly enhance wetland mapping success through the interpretation of elevation, breaks, slopes and object heights. However, this data was simply not available for the Highway 11 area, and therefore, the best data that could be acquired was used, that being the 2.5 m resolution SPOT imagery and the sections of digital aerial photos and Quikbird imagery. The results of the ground-truthing and the field-testing exercise indicate the limitation of using remote sensing imagery for the inventory and assessment of affected wetlands. In order to ensure the accuracy of wetland quantification, field validation is still a necessary component of such an assessment, particularly when dealing with very small or heavily vegetated wetlands. Nonetheless, it must be emphasized that lack of top-level imagery or orthophotography should not be considered adequate reason for not employing such a framework; even publically available 2.5 m resolution SPOT imagery will produce an assessment of potentially affected wetlands superior to much of the assessments undertaken currently.

This research outlined an area-based approach to wetlands CEA, given its practicality and ability to serve as a proxy to wetlands functioning. However, there are limitations to such an approach. The most significant of these is that many EA methodologies (i.e. checklists, ad hoc approaches) do not recognize wetlands beyond a certain size or class. For example, the Canadian Environmental Assessment Act states that a wetland must be covered by water for at least 3 consecutive months; a fact that limits wetland assessment and corresponding mitigation of significant impacts to larger, more permanent wetlands such as class 4 and 5 wetlands (see Stewart and Kantrud, 1971). This points to the limitation current EA legislation places on the achievement of no-net-loss for wetlands, particularly the discrepancies that will exist between 'significant' wetland effects identified by current EA practice with those of a CEA framework that does not base significance of impacts on wetland size.

The sample size and composition of the expert panel used for the AHP is a recognized limitation of the applied nature of the research, in terms of making recommendations for the Highway 11 case; however, it is telling of the state of wetland mitigation. Only those directly involved with wetlands, conservation and mitigation were willing to participate in the research – unfortunately these are often not the same people involved in the EA process where the advancement of science and wetland mitigation practices are much needed (see Cox and Grose, 2000; Brown and Veneman, 2001; Morgan and Roberts, 2003; King and Price, 2004). The manager and executive-type individuals who are the decision-makers that ultimately have the final say regarding the mitigation that takes place for affected wetlands, (and, it could be argued, might offer alternative views) were noticeably reluctant to complete the exercise. A much larger, more diverse sample population is required to strengthen the ability of results to be generalized and applied to other applications of wetland mitigation.

5.4 Advancing Practice: Research Directions

In order to address the inherent complexities involved with wetland assessment and subsequent decisions regarding mitigation, this research argued the need for, and demonstrated, a more structured and systematic approach to mitigating cumulative wetland impacts than what is currently being practiced. This framework set out to help fill a gap in the scientific and EA literature concerning good-practice methods/approaches for wetland effects assessment and mitigation early in the project planning and EA screening stages. In doing so, the intent is that the results of this research will help address the limitations of current assessment practices with regard to achieving no-net-loss of wetland function in project development. The key to maintaining no-net-loss is addressing the cumulative nature (direct and indirect effects combined) of project effects on the surrounding wetland environment. A structured, cumulative effects-based assessment and mitigation framework accomplishes this task through the following:

- a systematic approach for determination of the total potentially affected wetland area
- an objective analysis of comparisons between mitigation options
- a means to evaluate the sensitivity of mitigation options for determining critical thresholds for decision-influencing criteria affecting mitigation implementation
- a methodology that can be replicated across a variety of environments, development projects, and spatial scales

- an approach that assures the highest level of information available for mitigation decision-making through the application of an assessment and decision-making process guided by an explicit methodology

Research into the cumulative effects assessment of wetlands is riddled with obstacles to deter many a prospective researcher. Cumulative effects are ultimately about the future, the uncertain. Wetland functions are complex and cause-effect relationships often unknown. Add to this the fact that comprehensive wetland baseline data is rarely available and one gets an idea of the daunting nature of the subject. There are no concrete, absolute solutions or methods when it comes to wetlands cumulative effects assessment. The 'science' of wetlands mitigation has been built using an 'if it doesn't work, try something else' approach. There is little guidance, and even fewer methodologies, to ensure assessment and mitigation are done properly.

This research attempted to tackle some of the challenges of wetlands mitigation and cumulative effects assessment by adopting an expert-based approach, focused on the identification and analysis of alternative mitigation scenarios for managing potential cumulative effects. As such, the framework presented brought an explicit methodology and a 'more objectively-driven' approach to assessment and decision-making. Whereas many decisions regarding wetlands mitigation are subjectively made, based on insufficient data that, more often than not, leads to mitigation failure (NRC, 2001); this research chose to present mitigation through objectively-driven scenario-based analysis, focused on examining a range of possible future outcomes, such that informed decisions could be made about mitigation, and trade-offs made explicit in terms of achieving no-net-loss.

Any methodology designed for the cumulative effects assessment and mitigation of wetlands needs to be able to distinguish beyond direct and indirectly affected wetlands. For example, there needs to be some sort of distinction between various wetlands classified as indirectly affected in terms of the risk they may face regarding negative effects to the functions they provide. Making such a distinction is critical in terms of decision makers approaching the topic of mitigation from a cumulative effects standpoint. A cumulative effects assessment framework that simply stops after the delineation of affected wetlands into directly and indirectly affected wetlands will do little to advance the mitigation process towards a cumulative approach; decision makers will most likely be unwilling to mitigate for all wetlands having the potential to be negatively affected from the road development (i.e. all wetlands within the 500 m buffer). Therefore, lack of distinction as to the likelihood of negative effects beyond direct and indirect classification would most likely lead to mitigation being restricted to the current status quo (i.e. only the wetland 'area' directly affected), in which case the entire indirectly affected wetlands portion of the cumulative assessment is completely disregarded. However, by providing decision makers with scenarios outlining several choices of wetlands to be considered, including the risk of potentially adverse effects associated with those wetlands identified, they are given the opportunity to consider alternative levels and types of cumulative effects management, and the potential risks and opportunities involved with mitigating each.

It is recommended that assessment frameworks, such as that demonstrated in this research, be incorporated into new wetland policies that explicitly give consideration to cumulative effects assessment. As the push for a provincial wetland mitigation policy in Saskatchewan continues, the province would be making a great stride in the conservation of wetlands by including such a framework in provincial policy, and would at the same time, set precedence for future applications of wetlands mitigation focused on achieving no-net-loss.

5.5 Conclusion

The concept of CEA is not new, neither is the practice of wetland assessment and mitigation. The non-compliance of most projects to a no-net-loss policy for wetland function is a seemingly endless issue perpetuating the continual loss of wetlands across Canada. This research argued that a cumulative-effects approach to the assessment and mitigation of wetlands is a major stride towards achieving no-net-loss. Synergistically combining CEA, wetland impact assessment, and mitigation decision-making into an explicit methodology that practitioners can utilize for future development impacts is a positive contribution to ensuring the sustainability of wetland environments for decades to come. However, the loss of wetland habitat due to the impacts of development has been ongoing, and will continue to occur in the future unless there is a shift in the way wetland mitigation is performed and new methodologies implemented. The reality is that in a world bound by financial constraints, the practice of wetland mitigation has struggled to overcome the resource limitations hampering the ability to perform assessment and mitigation decision-making tailored towards managing cumulative loss. The rare incorporation of cumulative effects assessment is far too often the principle factor dictating the failure of mitigation plans at achieving no-net-loss. Yet, as the substantial loss of wetlands across the prairies attests to, it has never been more important to make conservation of wetlands, through the use of cumulative effects assessment, the prevailing force behind mitigation planning. Project proponents need methodologies and guidance to be able to weigh several different mitigation alternatives at once, such that all possible options are made explicit and an acceptable balance be found between the pursuit of no-net-loss and economic feasibility. This research was an initial step in that direction.

CHAPTER 6

LITERATURE CITED

Abbruzzese, B. and S.G. Leibowitz. 1997. Environmental Auditing: A Synoptic Approach for Assessing Cumulative Impacts to Wetlands. *Environmental Management*. 21(3): 457-475.

Antunes, P., R. Santos, and L. Jordao. 2001. The application of Geographical Information Systems to determine environmental impact significance. *Environmental Impact Assessment Review*. 21 : 511-535.

Austen, E. and A. Hanson. 2008. Identifying wetland compensation principles and mechanisms for Atlantic Canada using a Delphi approach. *Wetlands*. 28(3): 640-655.

Baxter, W., W.A. Ross, and H. Spaling. 2001. Improving the practice of cumulative effects assessment in Canada. *Impact Assessment and Project Appraisal*. 19(4): 253-262.

Baxter, W., W.A. Ross, and H. Spaling. 1999. To what standard? A critical evaluation of CEA in Canada. *Environmental Assessment*. 7(2): 30-32.

Beanlands, G.E. and P.N. Duinker. 1983. An Ecological Framework for Environmental Impact Assessment in Canada. Institute for Resource and Environmental Studies, Halifax.

Bedford, B.L. 1999. Cumulative effects on wetland landscapes: links to wetland restoration in the United States and southern Canada. *Wetlands*. 19(4): 775-788.

Bedford, B.L. and E.M. Preston. 1988. Developing the Scientific Basis for Assessing Cumulative Effects of Wetland Loss and Degradation on Landscape Functions: Status, Perspectives, and Prospects. *Environmental Management*. 12(5): 751-771.

Brinson, M.M. and R. Rheinhardt. 1996. The role of reference wetlands in functional assessment and mitigation. *Ecological Applications*. 6(1): 69-76.

Brooks R.P., D.H. Wardrop, and C.A. Cole. 2006. Inventorying and monitoring wetland condition and restoration potential on a watershed basis with examples from Spring Creek Watershed, Pennsylvania, USA. *Environmental Management*. 38: 673-687.

Brown, P.H. and C.L. Lant. 1999. The Effect of Wetland Mitigation Banking on the Achievement of No-Net-Loss. *Environmental Management*. 23(3): 333-345.

Brown, S.C. and P.L.M. Veneman. 2001. Effectiveness of compensatory wetland mitigation in Massachusetts, USA. *Wetlands*. 21(4): 508-518.

Conley, F.M. and G. van der Kamp. 2001. Monitoring the Hydrology of Canadian Prairie Wetlands to Detect the Effects of Climate Change and Land Use Changes. *Environmental Monitoring and Assessment*. 67(1-2): 195-215.

Cornish, E. 2004. Futuring: the exploration of the future. Bethesda, MD: World Future Society.

Costanza, R., R. d'Arge, R. de Groot, S. Farver, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, and M. van der Belt. 1997. The value of the world's ecosystem services and natural capital. *Nature*. 387(1): 253-260.

Cox, K.W. and A. Grose. (Eds.). 2000. Wetlands Mitigation in Canada: A Framework for Application. Sustaining Wetlands Issues Paper, 2000-1. North American Wetlands Conservation Council Ottawa, Ontario.

Cox, K.W. and A. Grose. (Eds.).1998. Wetlands Mitigation and Compensation: Proceedings of a National Workshop. Report 98-1. North American Wetlands Conservation Council. Ottawa, Ontario.

Dahl, T.E. and M.D. Watmough. 2007. Current approaches to wetland status and trends monitoring in prairie Canada and the continental United States of America. *Canadian Journal of Remote Sensing*. 33(1): 17-27.

Dube, M.G. 2003. Cumulative effect assessment in Canada: a regional framework for aquatic ecosystems. *Environmental Impact Assessment Review*. 23: 723-745.

Duinker, P.N. and L.A. Greig. 2007. Scenario analysis in environmental impact assessment: Improving explorations of the future. *Environmental Impact Assessment Review*. 27: 206-219.

Duinker, P.N. and L.A. Greig. 2006. The impotence of cumulative effects assessment in Canada: Ailments and ideas for redeployment. *Environmental Management*. 37(2): 153-161.

Environment Canada. 2007. Wetlands. Accessed from: http://www.ec.gc.ca/default.asp?lang=En&xml=540B1882-7E70-4B92-B5C8-D8FB3E23E935 on December 2, 2007.

Euliss Jr. N.H., R.A. Gleason, A. Olness, R.L. McDougal, H.R. Murkin, R.D. Robarts, R.A. Bourbonniere, and B.G. Warner . 2006. North American prairie wetlands are important nonforested land-based carbon storage sites. *Science of the Total Environment*: 361: 179-188.

Findlay, C.S. and J. Bourdages. 2000. Response Time of Wetland Biodiversity to Road Construction on Adjacent Lands. *Conservation Biology*. 14(1): 86-94.

Forman, R.T.T. and R.D. Deblinger. 2000. The ecological road-effect zone of a Massachusetts (U.S.A.) suburban highway. *Conservation Biology*. 14(1): 36-46.

Golder Associates Ltd. 2003. Canadian Environmental Assessment Act Screening Report for the Trans Canada East Twinning Project. Final Report 03-1361-027, 224pp.

Golder Associates Ltd. 2006. *Wetland and grassland habitat compensation plan for the trans Canada east twinning project and Highway No. 16 twinning project*. Final Report 03-1361-027/4010, 50pp.

Government of Alberta. 2007. Provincial Wetland Restoration/Compensation Guide. Alberta Environment. Edmonton, Alberta.

Government of Canada. 1993. A Guide to the Canadian Environmental Assessment Act. Canadian Environmental Assessment Agency. Ottawa, Ontario.

Government of Canada. 1991. The Federal Policy on Wetland Conservation. Environment Canada. Ottawa, Ontario.

Government of Saskatchewan. 1980. Environmental Assessment Act. Section 2d. Regina, Saskatchewan.

Goyal, S.K. and V.A. Desphande V.A. 2001. Comparison of weight assignment procedures in evaluation of environmental impacts. *Environmental Impact Assessment Review*. 21: 553-563.

Gutrich, J.J. and F.J. Hitzhusen. 2004. Assessing the substitutability of mitigation wetlands for natural sites: estimating restoration lag costs of wetland mitigation. *Ecological Economics*. 48(1): 409-424.

Harriman, J.A.E. and B.F. Noble. 2008. Characterizing project and strategic approaches to regional cumulative effects assessment in Canada. *Journal of Environmental Assessment Policy and Management*. 10(1): 25-50.

Hayes, N. and A. Morrison-Saunders. 2007. Effectiveness of environmental offsets in environmental impact assessment: practitioner perspectives form Western Australia. *Impact Assessment and Project Appraisal*. 25(3): 209-218.

Hegmann, G., C. Cocklin, R. Creasey, S. Dupuis, A. Kennedy, L. Kingsley, W. Ross, H. Spaling and D. Stalker. 1999. Cumulative effects assessment practitioners guide. Prepared by AXYS Environmental Consulting and CEA Working Group for the Canadian Evniornmental Assessment Agency. Hull, Quebec.

Hilden M., E. Furman, and M. Kalijonen. 2004. Views on planning and expectations of SEA: the case of transport planning. *Environmental Impact Assessment Review*. 24(5): 519-536.

Hilding- Rydevik T. and H. Bjarnadottir. 2007. Context awareness and sensitivity in SEA implementation. *Environmental Impact Assessment Review*. 27: 666-684.

Hirano, A., M. Madden, and R. Welch. 2003. Hyperspectral image data for mapping wetland vegetation. *Wetlands*. 23(2): 436-448.

Houlahan, J.E., P.A. Keddy, K. Makkay, and C.S. Findlay. 2006. The effects of adjacent land use on wetland species richness and community composition. *Wetlands*. 26(1): 79-96.

Jensen, J.R. 2005. Introductory Digital Image Processing: A Remote Sensing Perspective. 3rd ed. Prentice-Hall, Upper Saddle River, N.J.

Johnston, C. 1994. Cumulative Impact to Wetlands. *Wetlands*. 14(1): 49-55.

Kahn, H. and A. Wiener. 1967. *The Year 2000: A Framework for Speculation on the Next Thirty-three Years*. Macmillan, New York.

King, D.M. and E.W. Price. 2004. Developing Defensible Wetland Mitigation Ratios: A Companion to "The Five-Step Wetland Mitigation Ratio Calculator". NOAA Report. University of Maryland Center for Environmental and Estuarine Studies, Solomons, MD.

Lahdelma, R., P. Salminen, and J. Hokkanen. 2000. Using Multicriteria Methods in Environmental Planning and Management. *Environmental Management*. 26(6): 595-605.

Leibowitz, S.G. and Vining, K.C. 2003. Temporal connectivity in a prairie pothole complex. *Wetlands*. 23(1): 13-25.

Leibowitz, S.G., B. Abbruzzese, P.R. Adamus, L.E. Hughes, and J.T. Irish. 1992. A synoptic approach to cumulative impact assessment: A proposed methodology. US Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Oregon.

Li, J. and W. Chen. 2005. A rule-based method for mapping Canada's wetlands using optical, radar and DEM data. *International Journal of Remote Sensing*. 26(22): 5051-5069.

Lynch-Stewart, P., P. Neice, C. Rubec, and I. Kessel-Taylor. 1996. The Federal Policy on Wetland Conservation: Implementation Guide for Federal Land Managers. Canadian Wildlife Service, Environment Canada. Ottawa, Ontario.

MacDonald, L.H. 2000. Evaluating and Managing Cumulative Effects: Process and Constraints. *Environmental Management*. 26(3): 299-315.

Mitsch, W. J. and R. F. Wilson. 1996. Improving the success of wetland creation and restoration with know-how, time, and self-design. *Ecological Applications* 6. (1): 77-83.

Morgan, K.L. and Roberts, T.H. 2003. Characterization of Wetland Mitigation Projects in Tennessee, USA. *Wetlands*. 23(1): 65-69.

Morrison-Saunders, A, J. Arts, J. Baker, and P. Caldwell .2001. Roles and stakes in environmental impact assessment follow-up. *Impact Assessment and Project Appraisal*. 19(4): 289-296.

National Wetlands Working Group. 1997. The Canadian Wetland Classification System, 2nd edition. The Wetlands Research Centre, University of Waterloo. Waterloo, Ontario. Canada.

Natural Resources Canada. 2004. The Atlas of Canada: Wetlands. Accessed from http://atlas.nrcan.gc.ca/site/english/learningresources/theme_modules/wetlands/index.html. on November 28, 2007.

Noble, B.F. 2002a. The Canadian Experience with SEA and sustainability. *Environmental Impact Assessment Review*. 22: 3-16.

Noble, B.F. 2002b. Strategic Environmental Assessment of Canadian Energy Policy. *Impact Assessment and Project Appraisal*. 20(3): 177-188.

Noble. B.F. 2004. A multi-criteria analysis of Canadian electricity supply futures. The *Canadian Geographer*. 48(1): 11-28.

Noble, B.F. 2008. Strategic approaches to regional cumulative effects assessment: a case study of the Great Sand Hills, Canada. *Impact Assessment and Project Appraisal*. 26(2): 78-90.

Noble, B.F. and L.M. Christmas. 2008. Strategic Environmental assessment of Greenhouse Gas Mitigation Options in the Canadian Agricultural Sector. *Environmental Management*. 41: 64-78.

Noble, B.F. and J. Harriman. 2008. Regional strategic environmental assessment (R-SEA): Methodological guidance and good practice. Research report prepared for the Canadian Council of Ministers of Environment. Winnipeg, Manitoba

Noble, B.F. and K. Storey. 2001. Towards a Structured Approach to Strategic Environmental Assessment. *Journal of Environmental Assessment Policy and Management*. 3(4): 483-508.

NRC (National Research Council). 2001. Compensation for wetland losses under the Clean Water Act. National Academy Press, Washington, DC.

Ozesmi, S.L. and M.E. Bauer. 2002. Satellite remote sensing of wetlands. *Wetlands Ecology and Management*. 10(1): 381-402.

Peterson, E.B., Y.H. Chan, N.B. Peterson, G.A. Constable, R.B. Caton, C.S. Davis, R.R. Wallace, and Y.A. Yarronton. 1987. Cumulative Effects Assessment in Canada: An Agenda for Action and Research. Canadian Environmental Assessment Research Council. Hull, Quebec.

Preston, E.M. and B.L. Bedford. 1988. Evaluating Cumulative Effects on Wetland Functions: A Conceptual Overview and Generic Framework. *Environmental Management*. 12(5): 565-583.

Race, M.S. and M.S. Fonseca. 1996. Fixing compensatory mitigation: what will it take? *Ecological Applications*. 6(1): 94-101.

Robb, J.T. 2002. Assessing wetland compensatory mitigation sites to aid in establishing mitigation ratios. *Wetlands*. 22(2): 435-440.

Ross, W.A. 1998. Cumulative effects assessment: learning from Canadian case studies. *Impact Assessment and Project Appraisal*. 16(4): 267-276.

Risser, P.G. 1988. General Concepts For Measuring Cumulative Impacts on Wetland Ecosystems. *Environmental Management*. 12(5): 585-589.

Rubec,C.D.A. and A.R. Hanson. 2009. Wetland mitigation and compensation: Canadian experience. *Wetlands Ecology and Management*. 17: 3-14.

Saaty, R.W. 1987. The analytic hierarchy process- what it is and how it is used. *Mathematical Modelling*. 9(3): 161-176.

Saaty, T.L. 2008. Decision making with the analytic hierarchy process. *International Journal of Services Sciences*. 1(1): 83-98.

Sanchez, L.E. and A.L.C. Gallardo. 2005. On the successful implementation of mitigation measures. *Impact Assessment and Project Appraisal*. 23(3): 182-190.

Saskatchewan Transportation and Environment Committee. 2006. Wetland and Upland Mitigation Guidelines for Road Construction. Guideline No.1. November, 2006.

Semlitsch, R.D. and J.R. Bodie. 1998. Are Small, Isolated Wetlands Expendable? *Conservation Biology*. 12(5):1129-1133.

Smit, B. and H. Spaling. 1995. Methods for cumulative effects assessment. *Environmental Impact Assessment Review*. 15: 81-106.

Spaling, H. and B. Smit. 1993. Cumulative environmental change: conceptual frameworks, evaluation approaches, and institutional perspectives. *Environmental Management*. 17: 587-600.

Therival, R. and B. Ross. 2007. Cumulative effects assessment: Does scale matter? *Environmental Impact Assessment Review*. 27: 365-385.

Tiner, R.W. 2005. Assessing cumulative loss of wetland functions in the Nanticoke river watershed using enhanced national wetlands inventory data. *Wetlands*. 25(2): 405-419.

Tinker, L., D. Cobb, A. Bond, and M. Cashmore. 2005. Impact mitigation in environmental impact assessment: paper promises or the basis of consent conditions? *Impact Assessment and Project Appraisal*. 23(4): 265-280.

van der Kamp, G. and M. Hayashi. 1998. The groundwater recharge function of small wetlands in the semi-arid northern prairies. Great Plains Research. 8(1): 39-56.

van der Kamp, G. and M. Hayashi. 2009. Groundwater-wetland ecosystem interaction in the semiarid glaciated plains of North America. *Hydrogeology Journal*. 17: 203-214.

Velleman, P.F. and D.C. Hoaglin. 1981. Applications, basics, and computing of exploratory data analysis. Boston: Duxbury Press.

Voogd, H. 1983. *Multicriteria Evaluation for Urban and Regional Planning*. London: Pion.

Walters, D. and D. Shrubsole. 2005. Assessing efforts to mitigate the impacts of drainage on wetlands in Ontario, Canada. *The Canadian Geographer*. 49(2): 151-177.

Wickham, J.D., K.H. Riitters, T.G. Wade, and K.B. Jones. 2005. Evaluating the relative roles of ecological regions and land-cover composition for guiding establishment of nutrient criteria. *Landscape Ecology*. 20: 791-798.

Yang, W., X. Wang, S. Gabor, L. Boychuk, and P. Badiou. 2008. Water quantity and quality benefits from wetland conservation and restoration in the Broughton's Creek watershed. Ducks Unlimited Canada Research Report.

Zedler, J.B. 1996. Ecological issues in wetland mitigation: an introduction to the forum. *Ecological Applications*. 6(1): 33-37.

CHAPTER 7

APPENDIX

Mitigation Evaluation Exercise

CONSENT FORM

UNIVERSITY OF SASKATCHEWAN

Department of Geography

Dear: Participant

You are invited to participate in a study entitled "Mitigation options for road developments on prairie wetlands." You are being invited to participate based on your organization's involvement/ interest in wetland management. Your contact information was obtained from your organization's website or provided by key informants from the Government of Saskatchewan or Ducks Unlimited Canada. This study is in coincidence with the current 110 km twinning of Highway 11, between Saskatoon and Prince Albert, Saskatchewan. The objective of this study is to develop and test a rapid cumulative effects framework for identifying and evaluating mitigation options for wetlands potentially affected by road developments.

Researcher: Dr. Bram Noble, Department of Geography, University of Saskatchewan, Saskatoon, SK, S7N 5A5, Tel: 306-966-1899, E-mail: b.noble@usask.ca

Student: Jesse Nielsen, MSc. Candidate, Department of Geography, University of Saskatchewan, 86 Crestwood Crescent, Yorkton, SK, S3N 2P3, Tel: 306-783-8681, E-mail: jln974@mail.usask.ca

Purpose and Procedure: The overall purpose of this research is to better understand the relative importance of various criteria when making decisions regarding the optimal choice of mitigation scenarios for prairie wetlands affected by road development activities. Based on perceived involvement and/or interest that you and/or your organization may have regarding the mitigation of prairie wetland habitat, you are one of several 'expert' members identified to participate in this study.

In participating in this study, you will be asked to provide your expert judgment by assigning values or weights to a set of proposed criteria for evaluating wetland mitigation options, and then to evaluate each mitigation option on the basis of those criteria. The exercise is designed such that you should be able to complete the set of evaluation matrices in no more than 90 minutes, and you need not complete it in a single sitting.

Results of this study will contribute to a greater understanding of the application of prairie wetland mitigation and, to that end, may be of benefit to your organization/agency when undertaking development projects, evaluating project impacts, prescribing measures to improve current methods wetland mitigation, or providing direction for future applications of wetland mitigation.

Potential Risks: Your affiliation, but not your name, may be identified in research reports in order to lend credibility to the research. Given the limited number of participants, it may be possible to identify specific individuals based solely on organizational affiliation. However, you are being asked to provide your expert judgment and, as such, there is minimal personal risk. All data collected for this study will be reported in aggregate form only. Individual responses will not be revealed.

Potential Benefits: There are no direct benefits to you personally to participating in this study. The results will be used as part of a graduate MSc. thesis in the Department of Geography, and shared with various provincial and federal agencies and departments as recommendations to improve the effectiveness of wetland mitigation decision making in impact assessment and development planning.

Storage of Data: All information that you provide will be stored in a locked cabinet in the researcher's office at the University of Saskatchewan for a minimum of five years upon the completion of the study. After this time the transcripts and other materials will be destroyed.

Confidentiality: The data from this study will be published in scientific journals and may be presented at conferences and workshops/meetings; however, your personal identity will be kept confidential. You will be identified only by your position or professional affiliation (e.g. 'organization x'). However, because the participants for this study have been selected from a relatively small group of people, some of whom may be known to each other, it is possible that you may be identifiable to other people on the basis of your feedback to the research evaluation. In other words, only aggregate data will be presented in the research results, but confidentiality of your involvement as a participant is this study cannot be guaranteed. If, within 3 months following completion of the research evaluation, you have any second thoughts about your responses, you can contact the researcher or research assistant, who will immediately remove you from the data base and provide you with an opportunity to review your responses to determine whether you would like to withdraw from the research. After three months, it is likely that some form of research dissemination will already have occurred.

Right to Withdraw: Your participation is voluntary, and you may refuse to answer individual questions, however, please be advised that individual evaluation matrices are of little use if not completed. You are also free to withdraw from the research project for any reason, at any time, without penalty of any sort. If you withdraw from the research project, any data that you have contributed will be destroyed at your request. You are also free to withdraw your research responses from the study up to three months after the researcher has received your responses. After that time period it is likely that dissemination of the research will already have taken place.

Questions: If you have any questions concerning the study, please feel free to ask at any point; you are also free to contact the researcher or research assistant at the numbers provided above if you have questions at a later time. This study has been approved on ethical grounds by the University of Saskatchewan Behavioural Research Ethics Board in December 2008.

Any questions regarding your rights as a participant may be addressed to that committee through the Ethics Office (966-2084). Out of town participants may call collect. Your organization will be sent a copy of the research report upon completion of the study.

Consent to Participate: *"I have read and understood the description provided above; I have been provided with an opportunity to ask questions and my questions have been answered satisfactorily. By completing and returning the attached evaluation exercise I understand that I am giving my consent to participate in the study described above, and for any information that I provide to be used in the reporting of the study results. I also understand that I may withdraw this consent at any time by contacting the researcher."*

Participant ID # ____

SURVEY INSTRUMENT

Background to the Research Project

Wetlands are some of the most ecologically rich lands in prairie Canada, but every year they continue to be lost due to pressure from agriculture, industrial development, urbanization and the lack of mitigation to effectively deal with such pressure. The majority of activities that directly affect wetlands are either assessed at the screening level, where cumulative effects are rarely considered, or are deemed insignificant and do not trigger any formal environmental assessment process. As a result, the mitigation of cumulative effects on wetlands is often insufficient or completely lacking in development planning and decision-making. Part of the challenge is that there currently does not exist methodological guidance as to how to identify wetland mitigation and assessment needs that directly incorporates the consideration of potential cumulative environmental effects early in the project design process.

This research aims to develop and test a methodological framework and guidance for the integration of cumulative environmental effects in decision-making for project-based, wetland impact mitigation. The framework provides an opportunity for project proponents to strengthen mitigation commitments based on the explicit consideration of cumulative effects as part of project design and impact management strategies. For regulators, the framework provides a basis against which to identify the likely significance of a proposed development, evaluate the efficacy of mitigation commitments, and determine the need for a more comprehensive impact assessment.

This research project is part of a larger project aimed at developing a methodological framework for rapid CEA and mitigation of development activities on wetlands. The research will be applied to assist in mitigation decision making for wetlands potentially affected by the 110 km twinning of Highway 11, between Saskatoon and Prince Albert, Saskatchewan.

In completing this exercise, you will be asked to assign values to a set of proposed criteria for evaluating wetland mitigation options, and then to evaluate each mitigation option on the basis of each of the individual criteria.

Terms used in this Document

Mitigation: Strictly speaking, mitigation means to make less severe. In practice, wetland mitigation is most often limited to compensatory mitigation, which is a way of “making-up” for any damage that has been created (through enhancement; restoration or protection of other already existing wetlands; or creation of new wetlands).

Cumulative effects: Environmental effects that are additive, interactive, or synergistic in nature, caused by often individually minor, but collectively significant actions that accumulate over space and time. It is the cumulative loss of wetlands along the entire length of a development feature, regardless of individual wetland size or seasonality, which is of concern to this type of problem. Each individual effect may be insignificant, but the accumulation of the many insignificant effects causes a significant net-loss of wetland habitat and function.

Mitigation scenario: A scenario is a plausible but unverifiable account of change in a set of conditions over a defined period of time, depicting what could be if particular trends and types of events unfold. By comparing multiple scenarios, decision-makers are able to obtain a vivid picture of the likely consequences of different policies, mitigation plans, or courses of action. In this document, spatially explicit scenarios for mitigating the cumulative effects of linear developments on wetlands are identified, outlining different combinations of affected wetlands (directly and indirectly affected) to be considered within each scenario. The scenarios were created through the use of GIS software, selecting a subset of the total population of potentially affected wetlands based on their spatial distribution within the affected landscape.

Directly affected wetland: Direct effects will stem from those construction activities/impacts on wetlands occurring within the 31m highway right of way (ROW) and the 15m road alignment ROW (collectively termed ‘the zone of direct effects’), as defined by Saskatchewan Ministry of Highways and Infrastructure, for which wetland habitat and therefore functions (e.g. flood water control, ground water storage and filtration, protection of biodiversity, nitrogen and phosphorus sinks) is assumed to be completely lost. Wetlands that partially overlap the zone of direct effects are also considered to be directly affected if >50% of their area falls within the zone of direct effects.

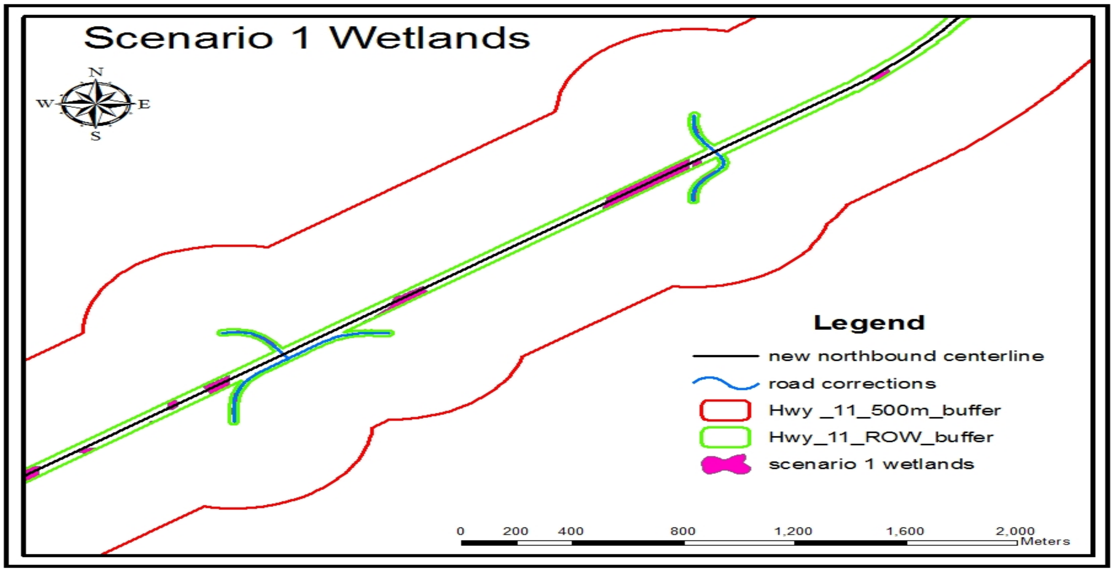
Indirectly affected wetland: Indirect effects refer to changes/degradation in the functions of that wetland area occurring outside the zone of direct effects, up to a distance of 500m away (measured from centerline of new highway and road correction lanes), which in accordance with the literature, was chosen as the boundary for our study area. This wetland will not experience area loss directly from construction activities, however, it ***may*** be part of, or connected to a wetland that is directly affected. Indirect effects may also be induced by landowner drainage of wetlands that are adjacent to any newly created ditches.

The direct and indirect effects along the entire length of the development feature, including the effects of other non-project-related stressors (such as landowner drainage), are interpreted here to be the total or ‘cumulative effect’ of highway construction and use.

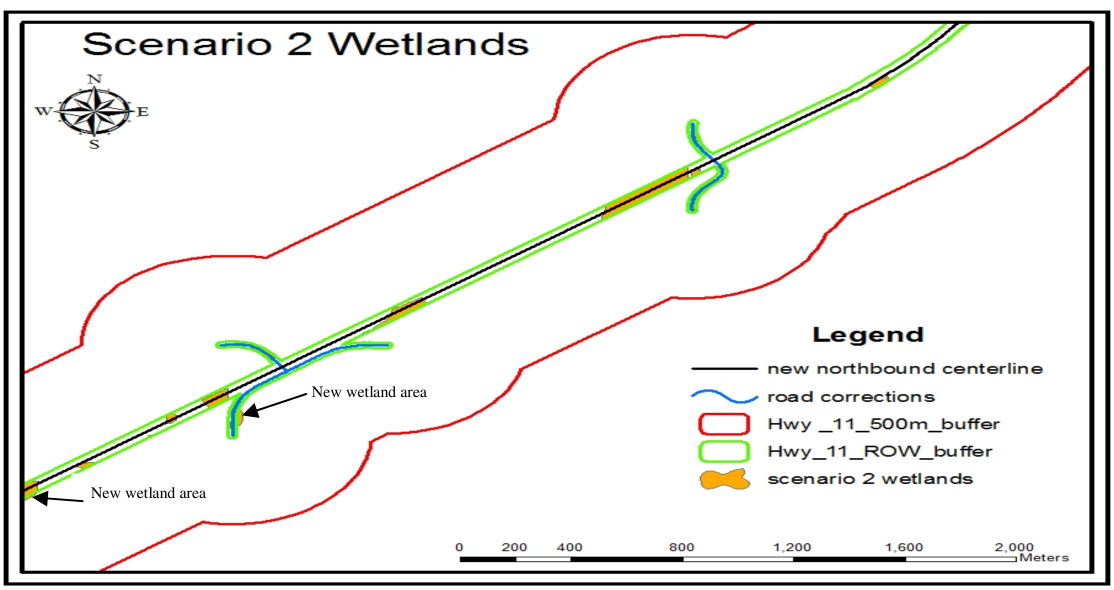
Wetland Mitigation Prescription Scenarios/Plans

Diagrams below represent a small portion of the entire potentially affected highway area

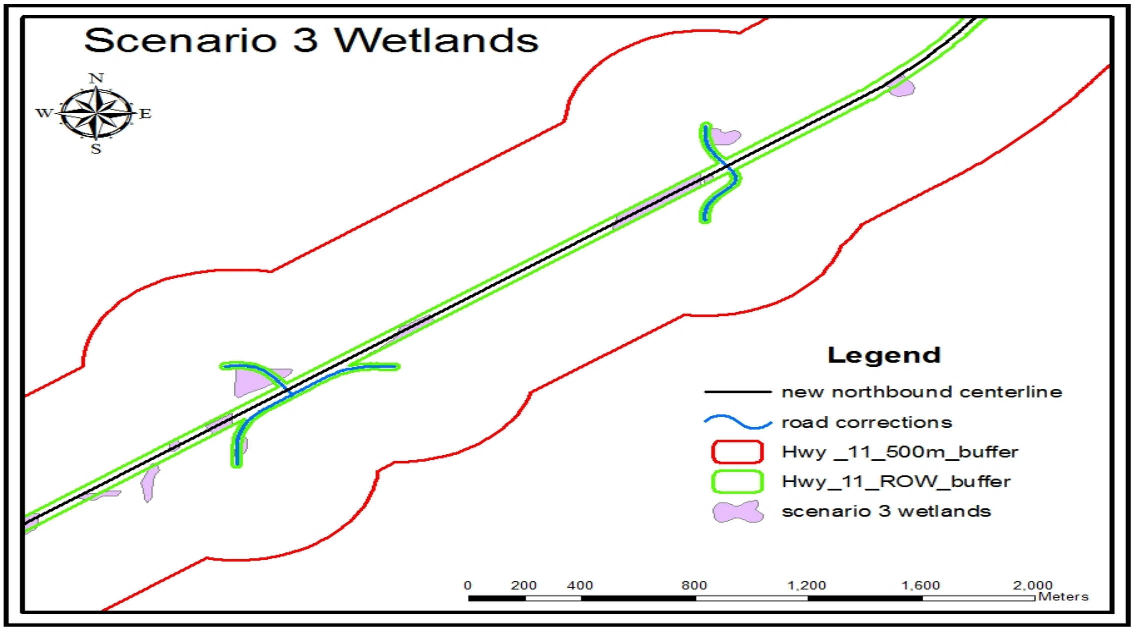
Scenario 1: Mitigation is prescribed for all wetland ***area*** completely within the 'zone of direct effects'. Any wetlands or wetland area that extends outside the 'zone of direct effects' is excluded from mitigation.



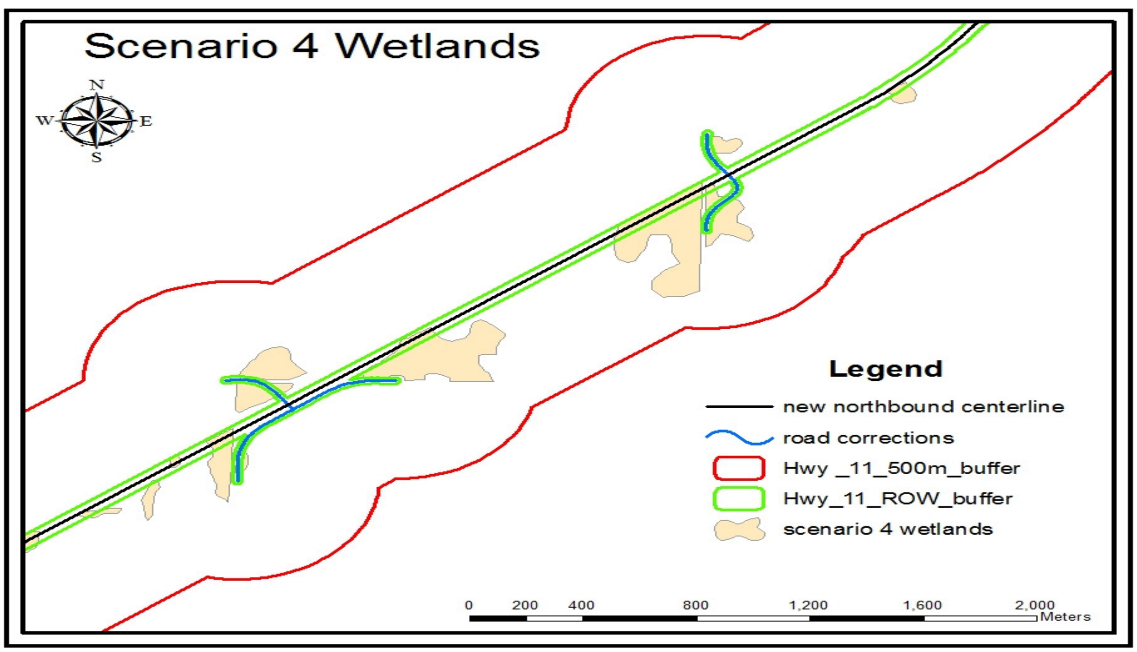
Scenario 2: Mitigation is prescribed for all wetlands in the 'zone of direct effects' plus mitigation of those wetlands that have >50% of their area within the 'zone of direct effect'.



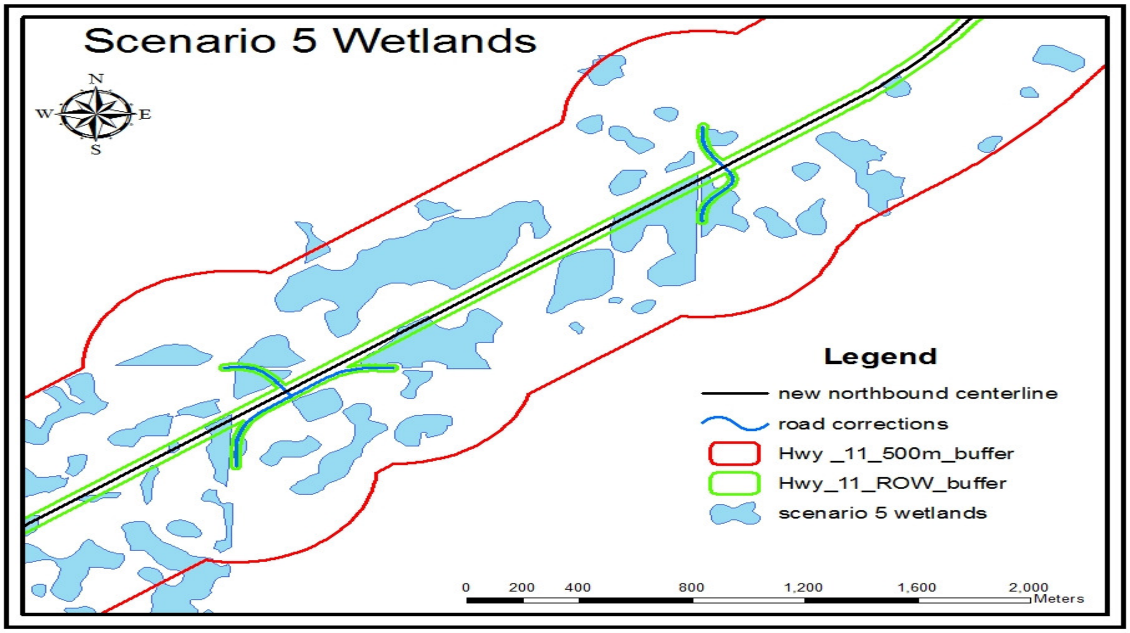
<u>Scenario 3</u>: Mitigation is prescribed for all wetlands identified in Scenario 2, plus all additional wetlands ≤ 2.0 ha that intersect or overlap with the 'zone of direct effect'.



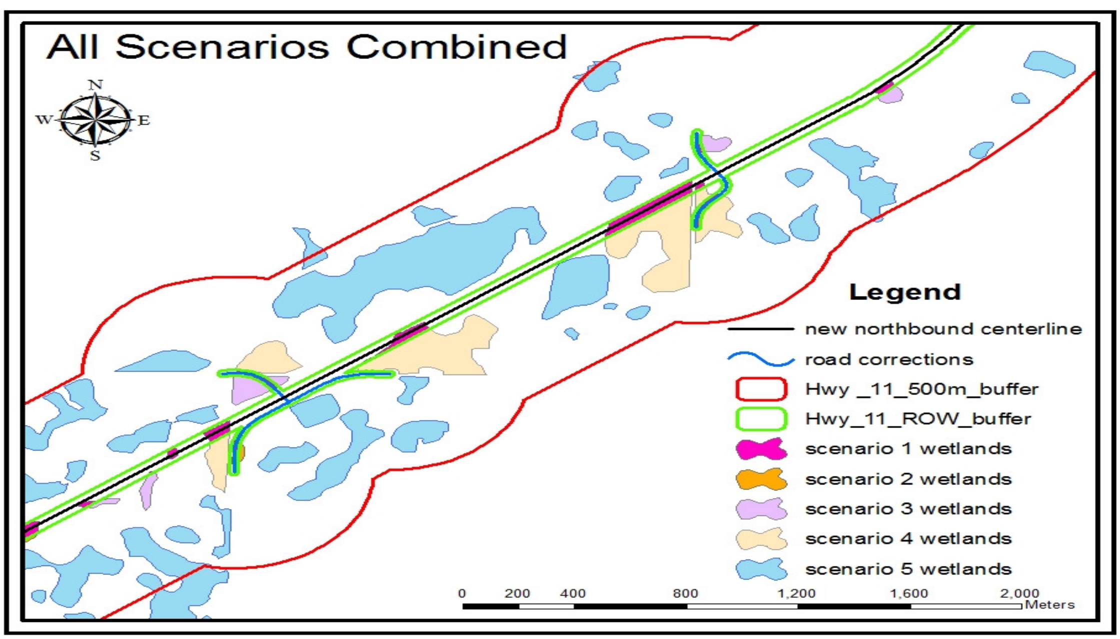
<u>Scenario 4</u>: Mitigation is prescribed for all wetlands within the 500 m study area buffer that intersect or overlap the zone of direct effect (the ROW buffer).



Scenario 5: Mitigation is prescribed for all wetlands that intersect or overlap the 500 m study area buffer.



All Scenarios Combined: Each scenario includes those wetlands of lower order scenarios (e.g. Scenario 3 includes the beige wetlands in addition to the fuchsia and orange of scenarios 1 and 2 respectively).



Wetland Mitigation Scenario Evaluation Criteria

There is no established single set of criteria for examining the efficient application of mitigation for wetland habitat affected by development projects.

However, based on review of the international literature for wetland mitigation and mitigation decision support in environmental assessment, six common criteria emerge as determining factors in the evaluation of mitigation applications to wetlands. These criteria are expressed below in terms of either maximizing or minimizing their respective characteristic

- ***Minimizing Financial Cost of Implementation* (*C_1*)**: Total monetary cost of carrying out a specific mitigation scenario/plan, including labour, land acquisition, and equipment/construction costs.

- ***Maximizing Compliance with a 'No-net-loss' Policy* (*C_2*):** Ability of a specific mitigation scenario/plan to account for the *total* loss of all wetland *function(s)* (e.g. flood water control, ground water storage and filtration, protection of biodiversity, nitrogen and phosphorus sinks) that were provided by the original wetlands and lost due to the development project.

- ***Minimizing Technical Complexity* (*C_3*):** The engineering or technical ease and practicality associated with the actual process of implementing a specific mitigation scenario/plan. In other words, the technical ease of performing mitigation for all the wetlands identified/considered within a specific scenario or plan.

- ***Maximizing Consideration of Cumulative Effects* (*C_4*):** Ability of a specific mitigation scenario/plan to ensure the sustainability of wetlands in the project environment by fully accounting for cumulative environment effects (both direct effects, such as grading and infilling of wetlands in a highway right-of-way, and indirect effects, such as change in chemical composition from road salt of adjacent wetlands), including also effects from other non-project-related stress (such as landowner drainage into drainage ditches newly formed by a project development).

- ***Minimizing Administrative Complexity* (*C_5*):** Ability of a specific mitigation scenario/plan to be carried out, from the planning phase to the actual in-field implementation, with minimum administrative complexity (e.g. minimizing permit requirements, minimizing complexity surrounding land ownership and access, minimizing number of involved organizations and consultations).

- ***Maximizing Public Acceptance* (*C_6*):** Degree to which a specific mitigation scenario/plan is likely to be perceived by the public as satisfactorily 'making-up' for the adverse cumulative effects of the proposed development.

Evaluation Exercise

Below are a series of evaluation matrices that you are asked to complete based on the proposed mitigation scenarios and evaluation criteria. In the first instance, you are asked to identify the relative importance of the evaluation criteria when designing a hypothetical mitigation plan. In the second part you are asked to evaluate each mitigation scenario/plan listed, relative to all others, on the basis of each individual criterion.

The approach adopts a paired-comparison technique, thus you need only complete the *unshaded* cells in each matrix. Instructions for completing the matrix, along with an example for each part of the evaluation exercise, are attached. This exercise should take no more than 1 hour of your time, and it need not be completed in a single sitting.

Please return your completed matrices to Jesse Nielsen by **email** at jln974@mail.usask.ca, or by **regular post** to:

Jesse Nielsen
86 Crestwood Cres.
Yorkton, SK. S3N 2P3

You may also return your matrices by **fax** to **306-966-5658**, Attn. Jesse Nielsen. However, please note that this fax number is shared by members of the Department of Geography and Planning. The confidentiality of your responses cannot be guaranteed if your organization is identified in the fax header.

If returning by fax, to help protect your confidentiality, please do not include your name on the assessment matrices. You have been assigned a participant identification code.

<u>*Note</u>: For those participants who were not originally contacted to participate and therefore, have not been assigned a participant identification code, and are needing to fax their results, please contact me by the above email and an identification code will be assigned to you. If mailing or emailing your results, please clearly indicate your name and affiliation so your results are identifiable.

If you have questions about completing the evaluation matrices, please feel free to contact me.

****Keep in mind, there are no wrong or right answers for this exercise, it's all a matter of what you think is important****

Part I: Paired Comparison Matrix for Criteria Evaluation

In this matrix you are asked to identify the relative importance of each of the proposed criteria in the evaluation of wetland mitigation options. In other words, which criteria are the most important criteria to you if you were designing a plan for the mitigation of impacted wetlands?

1. In each cell, check the box to indicate which of the two criteria is the most important.

2. Enter your value (from 1 to 9) on the adjacent line to indicate the relative importance of that criterion. If, in any given case, the criteria are considered equally important, simply enter a value of ‘1’. (see importance scale rating below)

Start with row 1 and compare criterion C_1 to C_2, C_1 to C_3, C_1 to C_4 and so on across the row. Then, move to row 2 and compare criterion C_2 to C_3, C_2 to C_4, C_2 to C_5 and so on across the row until all cells are complete.

Detailed instructions for completing the matrix, and an example of a completed, are appended to this document.

	C_1 Cost of implementation	*C_2 Compliance with no net loss policy*	*C_3 Minimizing technical complexity*	*C_4 Consideration of cumulative effects*	*C_5 Minimizing administrative complexity*	*C_6 Public acceptability*
C_1 Cost of implementation		C_1 ☐ ______ C_2 ☐	C_1 ☐ ______ C_3 ☐	C_1 ☐ ______ C_4 ☐	C_1 ☐ ______ C_5 ☐	C_1 ☐ ______ C_6 ☐
C_2 Compliance with no net loss policy			C_2 ☐ ______ C_3 ☐	C_2 ☐ ______ C_4 ☐	C_2 ☐ ______ C_5 ☐	C_2 ☐ ______ C_6 ☐
C_3 Minimizing technical complexity				C_3 ☐ ______ C_4 ☐	C_3 ☐ ______ C_5 ☐	C_3 ☐ ______ C_6 ☐
C_4 Consideration of cumulative effects					C_4 ☐ ______ C_5 ☐	C_4 ☐ ______ C_6 ☐
C_5 Minimizing administrative complexity						C_5 ☐ ______ C_6 ☐
C_6 Public acceptability						

Relative importance of the selected criterion:

9 = the criterion is *extremely* more important
8
7 = the criterion is *strongly* more important
6
5 = the criterion is more important
4
3 = the criterion is *slightly* more important
2
1 = the two criteria are of equal importance
* 2, 4, 6, and 8 are ‘intermediate’ values and can also be used in the rating

Part II. Evaluation of Mitigation Scenarios/Plans

Following the same procedure as above, you are now asked to evaluate the ability or capacity of each listed scenario/plan in terms of meeting the specified criterion. In other words, how do the mitigation scenarios compare to one another based solely on the specified criteria? You are asked to complete one matrix for each of the six criteria. You may find it convenient to have the criteria definitions and scenario maps alongside your matrices for reference.

1. In each cell, check the box to indicate which of the two scenarios is preferred in terms of meeting the specified criterion.

2. Enter your value (from 1 to 9) on the adjacent line to indicate the relative preference for that scenario (i.e. its ability or capacity to the criterion relative to the other scenario). If, in any given case, the criteria are considered equally important, simply enter a value of ‘1’.

Relative preference for/ ability of the scenario to meet the specified criterion:

9 = the scenario is *extremely* preferred
8
7 = the scenario is *strongly* more preferred
6
5 = the scenario is more preferred
4
3 = the scenario is *slightly* more preferred
2
1 = the two scenarios are of equal preference

* 2, 4, 6, and 8 are ‘intermediate’ values and can also be used in the rating

1. Scenario preferences based on: *Minimizing Financial Cost of Implementation* (*C_1*): Total monetary cost of carrying out a specific mitigation scenario/plan, including labour, land acquisition, and equipment/construction costs.

	Scenario $_1$	Scenario $_2$	Scenario $_3$	Scenario $_4$	Scenario $_5$
Scenario$_1$		S_1 ☐ ______ S_2 ☐	S_1 ☐ ______ S_3 ☐	S_1 ☐ ______ S_4 ☐	S_1 ☐ ______ S_5 ☐
Scenario $_2$			S_2 ☐ ______ S_3 ☐	S_2 ☐ ______ S_4 ☐	S_2 ☐ ______ S_5 ☐
Scenario $_3$				S_3 ☐ ______ S_4 ☐	S_3 ☐ ______ S_5 ☐
Scenario $_4$					S_4 ☐ ______ S_5 ☐
Scenario $_5$					

2. *Scenario preferences based on: Maximizing Compliance with a 'No-net-loss' Policy* (*C_2*): Ability of a specific mitigation scenario/plan to account for the *total* loss of all wetland *function(s)* (e.g. flood water control, ground water storage and filtration, protection of biodiversity, nitrogen and phosphorus sinks) that were provided by the original wetlands and lost due to the development project.

	Scenario $_1$	Scenario $_2$	Scenario $_3$	Scenario $_4$	Scenario $_5$
Scenario $_1$		S_1 ☐ ______ S_2 ☐	S_1 ☐ ______ S_3 ☐	S_1 ☐ ______ S_4 ☐	S_1 ☐ ______ S_5 ☐
Scenario $_2$			S_2 ☐ ______ S_3 ☐	S_2 ☐ ______ S_4 ☐	S_2 ☐ ______ S_5 ☐
Scenario $_3$				S_3 ☐ ______ S_4 ☐	S_3 ☐ ______ S_5 ☐
Scenario $_4$					S_4 ☐ ______ S_5 ☐
Scenario $_5$					

3. Scenario preferences based on: *Minimizing Technical Complexity* (*C_3*): The engineering or technical ease and practicality associated with the actual process of implementing a specific mitigation scenario/plan. In other words, the technical ease of performing mitigation for all the wetlands identified/considered within a specific scenario or plan.

	Scenario $_1$	Scenario $_2$	Scenario $_3$	Scenario $_4$	Scenario $_5$
Scenario $_1$		S_1 ☐ ______ S_2 ☐	S_1 ☐ ______ S_3 ☐	S_1 ☐ ______ S_4 ☐	S_1 ☐ ______ S_5 ☐
Scenario $_2$			S_2 ☐ ______ S_3 ☐	S_2 ☐ ______ S_4 ☐	S_2 ☐ ______ S_5 ☐
Scenario $_3$				S_3 ☐ ______ S_4 ☐	S_3 ☐ ______ S_5 ☐
Scenario $_4$					S_4 ☐ ______ S_5 ☐
Scenario $_5$					

4. Scenario preferences based on: *Maximizing Consideration of Cumulative Effects* (*C_4*): Ability of a specific mitigation scenario/plan to ensure the sustainability of wetlands in the project environment by fully accounting for cumulative environment effects (both direct effects, such as grading and infilling of wetlands in a highway right-of-way, and indirect effects, such as change in chemical composition from road salt of adjacent wetlands), including also effects from other non-project-related stress (such as landowner drainage into drainage ditches newly formed by a project development).

	Scenario $_1$	Scenario $_2$	Scenario $_3$	Scenario $_4$	Scenario $_5$
Scenario$_1$		S_1 ☐ ______ S_2 ☐	S_1 ☐ ______ S_3 ☐	S_1 ☐ ______ S_4 ☐	S_1 ☐ ______ S_5 ☐
Scenario $_2$			S_2 ☐ ______ S_3 ☐	S_2 ☐ ______ S_4 ☐	S_2 ☐ ______ S_5 ☐
Scenario $_3$				S_3 ☐ ______ S_4 ☐	S_3 ☐ ______ S_5 ☐
Scenario $_4$					S_4 ☐ ______ S_5 ☐
Scenario $_5$					

5. Scenario preferences based on: *Minimizing Administrative Complexity* (*C_5*): Ability of a specific mitigation scenario/plan to be carried out, from the planning phase to the actual in-field implementation, with minimum administrative complexity (e.g. minimizing permit requirements, minimizing complexity surrounding land ownership and access, minimizing number of involved organizations and consultations).

	Scenario $_1$	Scenario $_2$	Scenario $_3$	Scenario $_4$	Scenario $_5$
Scenario$_1$		S_1 ☐ ______ S_2 ☐	S_1 ☐ ______ S_3 ☐	S_1 ☐ ______ S_4 ☐	S_1 ☐ ______ S_5 ☐
Scenario $_2$			S_2 ☐ ______ S_3 ☐	S_2 ☐ ______ S_4 ☐	S_2 ☐ ______ S_5 ☐
Scenario $_3$				S_3 ☐ ______ S_4 ☐	S_3 ☐ ______ S_5 ☐
Scenario $_4$					S_4 ☐ ______ S_5 ☐
Scenario $_5$					

6. Scenario preferences based on: ***Maximizing Public Acceptance*** **(*C_6*):** Degree to which a specific mitigation scenario/plan is likely to be perceived by the public as satisfactorily 'making-up' for the adverse cumulative effects of the proposed development.

	Scenario $_1$	Scenario $_2$	Scenario $_3$	Scenario $_4$	Scenario $_5$
Scenario$_1$		S_1 ☐ ______ S_2 ☐	S_1 ☐ ______ S_3 ☐	S_1 ☐ ______ S_4 ☐	S_1 ☐ ______ S_5 ☐
Scenario $_2$			S_2 ☐ ______ S_3 ☐	S_2 ☐ ______ S_4 ☐	S_2 ☐ ______ S_5 ☐
Scenario $_3$				S_3 ☐ ______ S_4 ☐	S_3 ☐ ______ S_5 ☐
Scenario $_4$					S_4 ☐ ______ S_5 ☐
Scenario $_5$					

Instructions for Completion of Mitigation Exercise

The following instructions and explanations are included to help aid in the completion of the matrices.

Note: It is VERY important that you read all instructions and go over all examples and diagrams in order to make completion of the matrices as simple as possible.

1. The first thing you are asked to do is complete Part I: Paired Comparison Matrix for Criteria Evaluation. Your task here is to compare the relative importance of the 6 evaluation criteria to one another in terms of influencing decisions when mitigating wetland loss. In other words, think of a hypothetical case where it is identified that wetland habitat has been impacted by development activities, and therefore, requires a mitigation plan in the form of compensation to properly deal with the loss. You will need to ask yourself what criteria are the most important to consider or should most strongly influence the ***type*** of mitigation (i.e. restoring wetlands, creating new wetlands, protecting wetlands) and ***level*** of mitigation (i.e. do we only mitigate for wetlands directly affected by development impacts like grading and infilling or do we also consider indirect affects like habitat fragmentation and disruption of hydrological regimes) that will take place? In other words, what criteria will most strongly influence your mitigation plan?

   Examples:
   (Comparing C_1 to C_2) Should cost of the mitigation plan be more important when making decisions on the type and level of mitigation to undertake compared to the plan's ability to result in a no-net-loss of wetland functions.

   (Comparing C_2 to C_4) Is it more important to focus on a mitigation plan's ability to result in a no-net-loss of wetland functions or its ability to address cumulative effects? **Important distinction between the two criteria:* A No-net-loss of wetland function(s) is dependent on what is considered to actually have experienced impacts and may be fulfilled simply because cumulative effects haven't been considered.

   (Comparing C_3 to C_5) Is it more important to develop a mitigation plan based on the fact that it will be simple to technically complete (for example, protecting wetlands to compensate for impacted wetlands) compared to choosing a plan that doesn't create an administrative nightmare. In other words, what do you think is a stronger deciding factor in choosing a certain mitigation plan, the technical ease at which it can be completed or the least amount of administrative work involved?

   *These are the types of questions you should be asking yourself when making the comparisons between each and every criteria.

2. After completing Part I, you are then asked to compare 5 mitigation scenarios or plans to each other, based on how well you think they would fulfill each of the 6 criteria you've just finished with, in Part I. It is important to familiarize yourself with the Wetland Mitigation Prescription Scenario diagrams provided. Each of these diagrams depicts a unique mitigation scenario or plan. Each scenario or plan is differentiated from one another solely in terms of the ***level*** of mitigation that will take place (i.e. does it only identify mitigation for wetlands directly affected by development impacts like grading and

infilling or does it also consider wetlands that may experience indirect effects like habitat fragmentation and alteration of chemical compositions).

All wetlands along the Highway 11 development that <u>have potential</u> for being impacted (i.e. all wetlands extending out 500m on either side of the highway and road correction right-of-ways) were mapped using GIS. The 5 different scenarios were created to include certain wetlands (based on spatial location and size) out of the total amount of wetlands that were identified as <u>having potential</u> of experiencing some form of negative impacts from the twinning development.
Each scenario from 1 to 5 includes greater amounts of wetlands to be considered; from scenario 1, which if a mitigation plan was based on it, would only include directly impacted wetlands in the right-of-ways, up to scenario 5, which if you were to base a mitigation plan on it, you'd have to perform mitigation for every wetland within 500m of the highway and road corrections.

It may be useful to keep in mind the following numbers when comparing scenarios:
Scenario 1: Considers 3% of the total potentially affected wetlands.
Scenario 2: Considers 4% of the total potentially affected wetlands.
Scenario 3: Considers 6% of the total potentially affected wetlands.
Scenario 4: Considers 28% of the total potentially affected wetlands.
Scenario 5: Considers approx. 100% of the total potentially affected wetlands.

*It is important to note that the scenarios only represent the ***level*** of mitigation that will take place if a mitigation plan were made based on the wetlands identified in a specific scenario. In other words, they only represent the ***amount***, or which wetlands out of the total wetlands would qualify for mitigation if that particular scenario was deemed to adequately mitigate for the wetland impacts caused by the development.
*The scenarios do not include any reference to the ***type*** of mitigation (i.e. restoring wetlands, creating new wetlands, protecting wetlands) that would be undertaken in the mitigation plan once a certain scenario were chosen.

Your task in Part II is to determine which scenario would be the best in terms of optimizing the listed criteria of the particular matrix. In other words, you must first determine which scenario you would choose to base your mitigation plan on if your decision was based entirely on the one specific criteria listed for each matrix, and then rank that choice of scenario from 1 to 9 in terms of how much better it is than the other scenario you're comparing it to.

<u>Example:</u> Scenario preferences based on: *Minimizing Financial Cost of Implementation* *(C_1)*

Scenario 1 is better than Scenario 2 by a factor of 3 because it considers a bit less wetlands that will need mitigating, therefore, it will cost slightly less.

Scenario 1 is better than Scenario 5 by a factor of 9 because it considers substantially fewer wetlands that will need mitigating, therefore, it will cost much less.

In a similar fashion, complete all matrices, comparing scenarios to one another for each of the other criteria.

*Note: I have discovered that there may be difficulties with checking your choice, depending on what version of Word you have. As long as you indicate clearly in each cell which you are choosing (with an x next to the box for example), that will be fine.

APPENDIX- Examples for Completing the Evaluation Matrices

This exercise makes use of the 'paired-comparison' approach. In using this approach, the participant is asked to compare each criterion to every other criterion. Only ½ of the matrix needs to be completed, as the bottom diagonal is simply the reciprocal of the top diagonal of the matrix. In other words, if criterion 'i' is 5x more important than criterion 'j', then criterion 'j' must be 5x less important than criterion 'i'.

The paired comparison matrix lists the same criteria on each axis. In each cell of the matrix there are two criteria, and a space to enter a numerical score. There are two steps to completing a paired comparison matrix:

1. For each cell, you first identify by checking the box which of the two criteria presented is the 'more important' to consider in making a decision about an option (e.g. in evaluating wetland mitigation options)

2. Once the 'more important' criterion is identified, a value is entered on the line next to the two criteria to indicate the magnitude of importance, or the 'relative importance' of the chosen criteria relative to the other.

The relative importance of the criterion is rated on the following scale

9 = the criterion is *extremely* more important
7 = the criterion is *strongly* more important
5 = the criterion is more important
3 = the criterion is *slightly* more important
1 = the two criteria are of equal importance

* 2, 4, 6, and 8 are 'intermediate' values and can also be used in the rating

Start with row 1 and compare criterion C_1 to C_2, C_1 to C_3, C_1 to C_4 and so on across the row. Then, move to row 2 and compare criterion C_2 to C_3, C_2 to C_4, C_2 to C_5 and so on until all cells are filled.

In the example included below, for C_1 and C_2, criterion C_2 is identified as the more important criterion, and it is identified as 'strongly more important' than C_1.

For C_2 and C_4, criterion C_2 is identified as the more important criterion, and it is identified as 'strongly' to 'extremely' more important' than C_4.

For C_3 and C_4, they are identified as being equally important.

	C_1	C_2	C_3	C_4
C_1		C_1 ☐ __7__ C_2 ☑	C_1 ☐ ______ C_3 ☐	C_1 ☐ ______ C_4 ☐
C_2			C_2 ☐ ______ C_3 ☐	C_2 ☑ __8__ C_4 ☐
C_3				C_3 ☐ __1__ C_4 ☐
C_4				

The procedure is similar for evaluating the scenarios. The scenarios are compared based on their ability or capacity to meet a specified criterion. In the example below, the scenarios are being compared based on meeting criterion X.

In the matrix below, for scenario S_1 and S_2, the preference in terms of meeting criterion x is for S_2. A value of 9 indicates that S_2 is extremely more preferred in terms of meeting criterion X than S_1. In other words, S_2 has an extremely greater ability, capacity, or potential to meet criterion X than does S_1.

For scenario S_2 and S_3, the preference in terms of meeting criterion x is for S_2. A value of 3 indicates that S_2 is only slightly more preferred in terms meeting criterion X than S_3.

For scenario S_3 and S_5, the scenarios are equally preferred based on their ability, potential, or capacity to meet criterion x.

Scenario preferences based on: *meeting criterion X*

	Scenario $_1$	Scenario $_2$	Scenario $_3$	Scenario $_4$	Scenario $_5$
Scenario$_1$		S_1 ☐ ___9___ S_2 ☐X	S_1 ☐ ______ S_3 ☐	S_1 ☐ ______ S_4 ☐	S_1 ☐ ______ S_5 ☐
Scenario $_2$			S_2 ☐X ___3___ S_3 ☐	S_2 ☐ ______ S_4 ☐	S_2 ☐ ______ S_5 ☐
Scenario $_3$				S_3 ☐ ______ S_4 ☐	S_3 ☐ ___1___ S_5 ☐
Scenario $_4$					S_4 ☐ ______ S_5 ☐
Scenario $_5$					